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ABSTRACT

This sourcebook contains a collection of laboratory exercises assembled for use in introductory physical geography classes taught at community colleges. Introductory sections address the origins of the sourcebook, the ways it differs from traditional laboratory manuals, and its form and anticipated use. Next, a list of terms or concepts, preparatory information, and exercises are presented for 10 topic areas: (1) the Geographic Grid and Time Zones; (2) Earth-Sun Relationships; (3) Contour and Topographic Maps; (4) Solar Energy; (5) Atmospheric Moisture; (6) Weather Maps; (7) Classifying Global Climate Patterns; (8) Soil Components and Characteristics; (9) Rating Curves and Recurrence Intervals (Hydrology); and (10) Applications of Topographic Maps in Specific Subfields. Lab exercises for each topic are ordered from easiest to most difficult. (LAL)

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INTRODUCING PHYSICAL GEOGRAPHY

ED265889

A Laboratory Sourcebook for Community Colleges

OUR GLOBAL EARTH

UNDERSTANDING TOPOGRAPHIC MAPS

ATMOSPHERIC PROCESSES AND WEATHER PATTERNS

CLIMATIC CLASSIFICATIONS

SOILS

HYDROLOGY

TOPOGRAPHIC MAPS AND GEOMORPHIC PROCESSES

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INTRODUCING PHYSICAL GEOGRAPHY

A LABORATORY SOURCEBOOK

FOR COMMUNITY COLLEGES

Project sponsored by

Dean Juan Francisco Lara, Office of Academic Interinstitutional Programs,
University of California, Los Angeles

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This laboratory sourcebook may be purchased from the Office of Academic Interinstitutional Programs, 1332 Murphy hall, UCLA, Los Angeles, California 90024, (213) 825-2531

ACKNOWLEDGEMENTS

The initial impetus for this collection of labs arose from a seminar on laboratory exercises for introductory physical geography given at UCLA for local community college geographers. The seminar was one in a series initially supported by Associate Vice-Chancellor John C. Ries and the Office of Undergraduate Affairs, and later co-sponsored by Dean Juan Francisco Lara of the Office of Academic Interinstitutional Programs and the UCLA Department of Geography. Based upon the reaction of the participants to the seminar, Dean Lara suggested that a collection of laboratory exercises be assembled for use in the Community Colleges. His office generously funded this project, and Kit Salter of that office oversaw the production of this booklet.

Most of the exercises were developed in recent years at UCLA, through the efforts of many geography teaching assistants and a few faculty members. Several community college geographers: Bill Russell of Los Angeles City College; Bob Sager of West Los Angeles College; James Sullivan of East Los Angeles College; Mark Powell of Los Angeles Pierce College; and especially Bob Brown of Rio Hondo College, also contributed exercises and suggestions to this collection. The final compilation was put together with the help of Jeff Lee, Linda O'Hirok, Betsy Atwater and Dirk Hudson. The suggestions and efforts of Gail Hobbs of Pierce College during the final stages of editing and preparation were invaluable, and greatly appreciated. I am grateful for the cooperation and assistance of all these individuals. Finally, I wish to thank Tom McKnight, then chairman of our department. He supported this project from its original inception and has continued to provide encouragement throughout its development.

Frank H. Weirich
Department of Geography
UCLA

FOREWORD

At the present time there are numerous laboratory manuals available which provide exercises for use in introductory physical geography courses. Some, such as Strahler's Exercises in Physical Geography, have been available for many years while others, such as Heyl and Brook's Introduction to Landforms and Suckling and Doyon's Studies in Weather and Climate, are relatively recent additions. While the availability of these materials has greatly assisted those teaching such courses, there appear to be several problems associated with the use of such manuals. One major difficulty involves the general character of many manuals. Not surprisingly, many are closely aligned with a specific text. If, for whatever reason, one chooses not to use the specific text involved, it is often difficult to use the laboratory manual effectively. A second and not entirely unrelated problem involves the fact that the manuals are prepared with a broad market in mind. Many of the labs use data and situations which may be foreign to the students. This is inherently undesirable, in that it often makes it more difficult to successfully convey the basic concepts to students when they lack any feeling for the physical settings being used in the exercises.

This collection is an attempt to come to terms with these deficiencies. It is not a laboratory manual in the traditional sense. It does not contain a specific set of laboratories which a class is asked to complete exercise by exercise. It is also not keyed to any specific text. Instead, it consists of a set of specific topics, an understanding of which would be considered central to any basic physical geography course. Ten such topic areas have been defined. At the beginning of each topic a list of terms or concepts is presented. These are considered to be essential to an understanding of the particular topic under discussion and form the basis of the laboratory exercises. The list of concepts is followed in some topic areas with a more detailed presentation of

principles. While most texts will adequately cover the requisite terms and concepts listed, there are sometimes major gaps. In such situations an effort has been made to include a somewhat more detailed outline of material necessary for the completion of the exercises. Following this preparatory information are the laboratory exercises themselves. Generally they are ordered within each topic from easiest to most difficult, although in many situations the distinctions in difficulty will be relatively small and the differences will involve variation in the emphasis of specific exercises. For the most part, local examples have been used.

This approach should offer several advantages over other structures. The use of key concepts frees the instructor from relying upon any particular text. The choice of different exercises on the same topic should allow more flexibility, enabling the instructor to more carefully tailor the exercises to the needs of an individual class. The availability of several exercises on the same topic should also allow individual instructors to develop their own exercises by merging material from several of the exercises. The use of local or regional examples should make the comprehension of the basic concepts somewhat less difficult and may well increase the interest of the students in the questions under discussion.

No claim is made for the completeness of this set of topics or exercises. Clearly, not all the possible topics which might be included in a course are covered. This is partially a reflection of the limited length of many of the courses taught. A quarter or semester system severely limits the amount of material which may be covered. The selection also reflects the bias inherent in the courses taught at UCLA. Many topics which might well be included in other introductory physical geography course structures are either deferred to a higher level or are dealt with under parallel courses, such as biogeography.

We have, then, a collaborative effort at producing a collection of laboratory exercises for introductory physical geography. We hope they will be widely useful. F.W.

INTRODUCTION

When I first had the opportunity to teach a physical geography laboratory, Dean Juan Lara was kind enough to make available to me a first draft copy of this laboratory sourcebook, which, in addition to the lab manual and materials used by my predecessor, became the basis from which I formulated my semester's exercises. Inasmuch as the community college semester is longer than the UCLA academic quarter around which the sourcebook was designed, my course included substantially more topics than presented here. The booklet, however, proved to be quite useful as a collection of exercises from which to choose items that seemed appropriate to my particular situation.

One of the numerous benefits of the UCLA Geography Department/Community College seminars has been the exchange of information and ideas among the participants. This sourcebook is an outgrowth of that exchange, presented in a concrete form as exercises that can be utilized in a geography lab in several ways: intact as they are presented in the manual; modified to suit your individual needs; or simply as a source of ideas from which to create your own lab exercises. The real benefit here is that these are materials which have been tried in classroom lab situations by your colleagues and have proven successful.

We are well aware of, and have discussed at our seminar gatherings, the wide ranging academic backgrounds and abilities of our students; many of those students have little or no pre-collegiate geographical education. The depth to which a topic is covered and the difficulty of the exercise can be determined by each instructor. In many instances there are a goodly number of exercises under a particular topic, varying in depth and skill level required. The standard laboratory manuals do not take this into account.

Some of the materials, namely the computer-based exercises on solar energy, may not be applicable to our present community college programs; but since we are meeting

at UCLA several times a year for the purpose of updating our geographical background and learning what is new in geographic education, the inclusion of these materials may give us some sense of areas to investigate and may be a relevant means of bringing us and our classes into the computer age, even if superficially. Perhaps we could work with the computer science departments on our campuses to integrate computers into one or two exercises as yet another tool that geographers utilize.

Professor Weirich stated in his foreword that this sourcebook was not designed to be a complete laboratory manual, but rather a starting point or perhaps a supplement to materials being used. As this manual is used, tested, and evaluated by community college lab instructors, we may suggest additional exercises for topics covered and perhaps in the future produce an expansion of this sourcebook to include even more themes.

Gail Hobbs
Los Angeles Pierce College
Los Angeles Community College District

OUR GLOBAL EARTH

I. THE GEOGRAPHIC GRID & TIME ZONE

The basic concepts of location and time are an appropriate starting point for most students. Surprisingly, many have considerable difficulty coming to terms with the geographic grid and time zones. The problem is not so much a conceptual one as a practical one. They simply have a hard time getting used to using the coordinate system and working with time zones. Given such difficulties and the importance of time and locational referencing, an entire lab devoted to these concepts appears in order. The emphasis in the following grid and time zone labs is upon obtaining practice in applying the grid and time zones in specific examples.

Concepts to Cover

Latitude

Longitude

Rotation of the earth

Time zones and longitude

How time zones work and are used

The International Dateline

Prime Meridian and its use as a reference point

Version A

1. On a world map, locate (to the nearest degree) the following:
   (a) Baghdad, Iraq _____
   (b) Sydney, Australia _____
   (c) the southern tip of Baja California, Mexico _____
   (d) San Francisco, California _____

2. What city or feature is located at:
   (a) 34°N 118°W _____
   (b) 17°N 100°W _____
   (c) 0° 50°W _____
   (d) 51°N 0° _____

3. How many degrees does the earth rotate in one day? _____ in one hour? _____

4. A place 30° east of you will have sunrise (sooner/later) than you by _____ hours.

5. At what longitude is it 8:00 p.m. when it is noon in London? _____

6. If it is noon Tuesday in Honolulu, what day and time is it in Tokyo? _____

7. It is 12:30 p.m. in San Francisco. What time is it in San Diego? _____

Version B

A. Locate the following cities by their latitude and longitude (to the nearest degree).

1. Milwaukee, Wisconsin _____
2. Athens, Greece _____
3. Moscow, USSR _____
4. Denver, Colorado _____
5. Santiago, Chile _____
6. Auckland, New Zealand _____
7. San Diego, California _____
8. Fort Yukon, Alaska _____
9. Quito, Ecuador _____
10. Nairobi, Kenya _____

B. What is at the following coordinates?

1. 52° S, 60°W _____
2. 90° S, 0° E _____
3. 90° N, 90° W _____
4. 0°, 0° _____
5. 1° N, 104° E _____
6. 30° S, 30° E _____
7. 20° N, 156° W _____
8. 19° N, 99° W _____
9. 40° N, 75° W _____
10. 0°, 90° W _____

1. If it is noon in New York, what time is it in:
   - Minneapolis? _____
   - Seattle? _____
   - Denver? _____
   - Anchorage? _____
   - Honolulu? _____
   - Boston? _____

2. Using a 24 hour clock, change the following:
   - 2:00 p.m. _____
   - Midnight _____
   - 6:20 p.m. _____
   - 1:30 p.m. _____
   - 1:30 a.m. _____
   - 10:30 a.m. _____

3. If it is 8:00 p.m. Wednesday in Chicago, what time and day is it in Tokyo (135° E)? _____

4. If it is 1:00 p.m. Thursday at 15°E, what time is it at 75° W? _____

5. If it is 3:00 a.m. Wednesday at 30° E, what time is it at 30° W? _____

6. If it is 6:00 p.m. Saturday at 150° W, it is 1:00 p.m. Sunday at? _____

7. If it is 12:00 noon Sunday at 90° W, it is 8:00 p.m. Sunday at? _____

8. If it is 4:00 p.m. (1600 hours) G.M.T. (Greenwhich Mean Time), what time is it in Los Angeles (on the 24 hour clock)? _____

9. If it is 11:00 a.m. Sunday in Sydney, Australia (150°E), what time and day is it in New York? _____

10. It is 4:20 p.m. in Miami, Florida. Change this to G.M.T. _____

11. If it is 1:30 a.m. Sunday in Paris, France (C.E.T.), what time and day is it in Los Angeles (P.S.T.)? _____

12. It is 10:00 p.m. Monday in Chicago, Illinois. Change this to G.M.T. _____

13. If it is 11:00 a.m. in Washington, D.C., what time is it in Quito, Ecuador? _____

14. If you depart Los Angeles International Airport at 11:00 p.m. Sunday, when will you arrive at J.F.K. International Airport in New York City? (Your flight time is five hours.) _____

15. If you depart Paris (C.E.T.) at 1:30 a.m. Tuesday on the Concorde, what time and day will you arrive in Washington, D.C. (E.S.T.)? (Your flight time is three and a half hours.) _____

Version C

1. How many degrees does the earth rotate in one day? _____ In one hour? _____ In one minute? _____
   There is, then, a difference in sun time of one hour for every _____ degrees of longitude.

2. A place 45° east of you will have sunrise (sooner/later) than you do by _____ hour(s). A place 60° west of you will have noon (sooner/later) than you do by _____ hour(s).

3. What is the longitude of a station whose local sun time is 7:00 a.m. when it is noon in London? _____
   What is the longitude of a station whose local sun time is 7:00 p.m. when it is noon in London? _____

4. When it is 3:30 a.m. on Tuesday in London, what is the time and day in Las Vegas (105° W)? _____
   When it is 6:45 p.m. on Tuesday in Las Vegas, what is the time and day in London? _____

5. Locate Honolulu on a map. If it is 12:00 noon on Thursday, what would be the time and day in Tokyo? _____

6. You depart Los Angeles (34° N, 120° W) at 5:00 p.m. on a five hour flight to New Orleans (30°N, 90°W). What is the local time (in New Orleans) of your arrival? _____
   Your return flight (New Orleans to Los Angeles) departs at 10:00 a.m. and has a stopover in Phoenix, which adds one hour to your previous flight time. What is your time of arrival in Los Angeles? _____

Version D

The purpose of this exercise is to give you experience in determining the latitude and longitude of particular places and the experience of locating a place knowing only a pair of coordinates.

The exercise requires you to make use of the wall maps in the room as well as selected maps in your atlas.

1. Using the appropriate maps in your atlas, determine the latitude and longitude, to the nearest degree, of the following places:

   a. Cheyenne, Wyoming _____
   b. Tehran, Iran _____
   c. Salisbury, Zimbabwe _____
   d. Moscow, U.S.S.R. _____
   e. Rio Gallegos, Argentina _____
   f. South Magnetic Pole _____
   g. North Magnetic Pole _____
   h. Cartagena, Spain _____

2. Identify the cities located at the following positions:

   a. 19° N 99° W _____
   b. 38° S 145° E _____
   c. 76° N 69° W _____
   d. 49° N 09° E _____
   e. 78° S 108° E _____
   f. 33° N 97° W _____
   g. 34° N 118° W _____

3. Determine the latitude and longitude of the following places:

   a. Regina, Saskatchewan, Canada _____

   b. Melbourne, Australia _____

   c. Kinshasa, Zaire _____

   d. New Delhi, India _____

   e. Antofagasta, Chile _____

4. Of the cities in number three, which is farthest?

   north _____

   south _____

   east of Greenwich _____

   west of Greenwich _____

5. Locate the cities at the given coordinates.

39°45N	105°W	_____
41°45N	87°49W	_____
35°05N	106°47W	_____
38°39N	121°30W	_____
25°49N	80°06W	_____

6. Give the latitude and longitude of the following places:

   (a) Intersection of the equator and the prime meridian. _____

   (b) A point one-third of the way from the equator to the north pole and one quarter of the way eastward from the prime meridian. _____

   (c) A point one-half way from the equator to the south pole and one-half of the way westward from the prime meridian to the 180th meridian. _____

   (d) The mouth of the Colorado River. _____

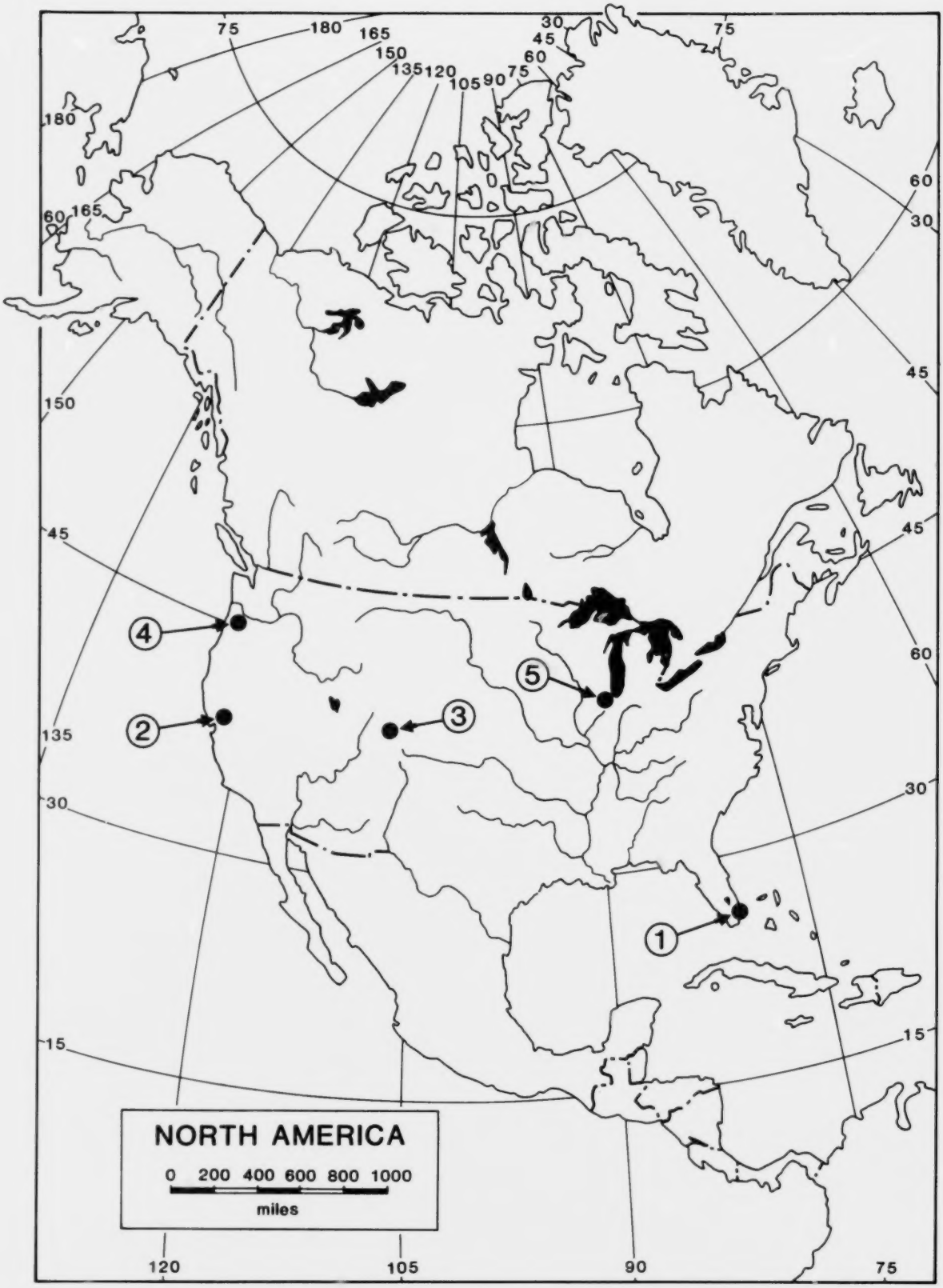
7. What Norwegian city is located on the Varanger Fjord about 70°N latitude? Approximately how many miles is it from the North Pole? _____

8. What large American city is directly west of Cairo, Egypt? _____ What is its latitude? _____

9. What is the latitude of the northernmost point of Alaska? _____ Or of the southernmost point in Florida? _____

10. These questions refer to the map on the following page. Use the map of the United States in your atlas to assist you. First, name the cities referred to by number; second, give their latitude and longitude.

NAME	LATITUDE & LONGITUDE
1._____	_____
2._____	_____
3._____	_____
4._____	_____
5._____	_____


NORTH AMERICA
0 200 400 600 800 1000
miles
1
2
3
4
5
75
180
165
150
135
120
105
90
75
30
45
60
75
180
60
165
150
45
60
30
45
45
60
135
30
30
15
15
120
105
90
75

2. EARTH-SUN RELATIONSHIPS

In dealing with earth-sun relationships, students appear to have the greatest difficulty relating the terminology generally used to the actual sequence of events in the annual cycle. In addition to carefully working through the definitions, it is essential that the associations and relationships present between different chronological points and different points in the solar cycle be clearly recognized.

Generally speaking, unless a basic understanding of earth-sun relationships is clearly established at an early stage it becomes very difficult to deal with variation in solar radiation received at the surface and all subsequent dealings with radiation balances in the earth atmosphere system.

Concepts to Cover

Revolution of earth about sun

Rotation of earth

Perihelion

Aphelion

Plane of ecliptic

Polar axis

Tropic of Cancer

Tropic of Capricorn

Arctic Circle

Antarctic Circle

Summer solstice

Winter solstice

Vernal equinox

Autumnal equinox

Sub solar point

Sub angles

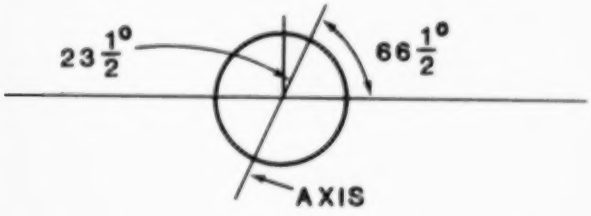
Circle of Illumination

Atmospheric attenuation

Variation in day length

A more detailed discussion of specific concepts

- Direction of rotation--west to east--counterclockwise at the North Pole
- Direction of revolution--counterclockwise around the sun when viewed from above the North Pole
- Shape of the earth's orbit--elliptical--sun occupies a focus of the ellipse
- Perihelion--earth is closest to the sun on January 3--91.5 million miles
- Aphelion--earth is farthest from the sun on July 4--94.5 million miles, mean difference is 93 million miles. This difference has no effect on the amount of solar radiation received by the earth.
- Inclination of the earth's axis causes seasonal change in insolation
- Plane of the ecliptic--imaginary plane containing the earth's orbit around the sun
- Polar axis--imaginary line through the center of the earth around which the earth rotates--the axis runs from pole to pole
- The polar axis is inclined 23.5° from the perpendicular to the plane of the ecliptic--or 66.5° from the plane of the ecliptic itself.

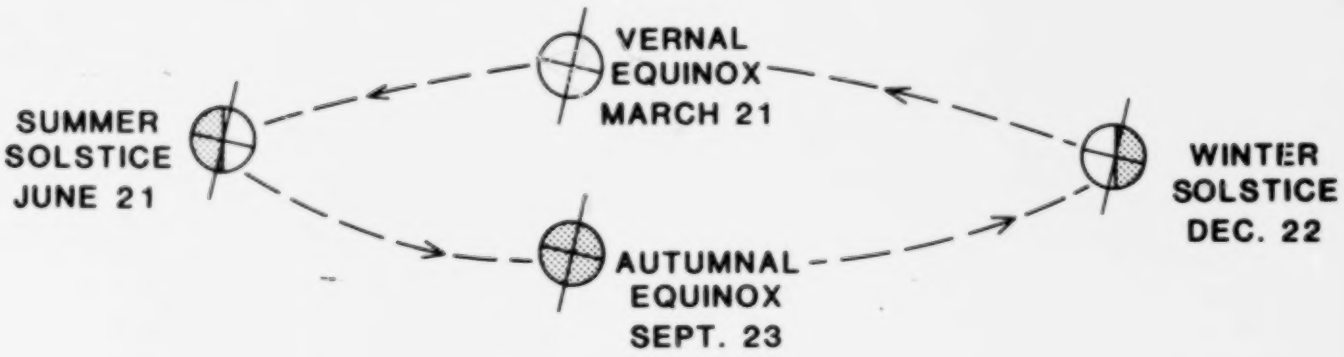


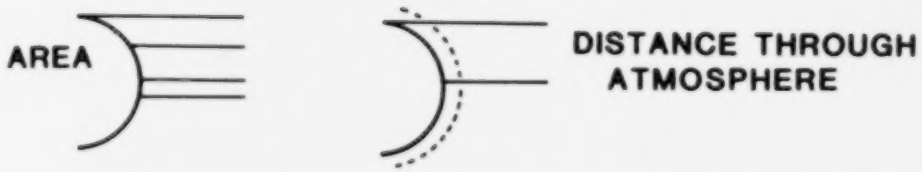
- Parallelism--the polar axis maintains a fixed orientation with respect to the stars--the axis doesn't wobble around.

DEMONSTRATE HOW THE EARTH REVOLVES AROUND THE SUN

- Circle of illumination--separates night from day

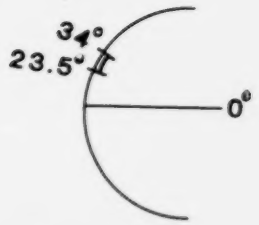
- o Vernal Equinox March 21
  --circle of illumination runs pole to pole
  --sun's rays strike the earth at a 90° angle on the Equator
  --equator called the subsolar point
- o Summer Solstice June 21
  --subsolar point the Tropic of Cancer 23.5° N
  --north of Arctic Circle gets 24 hours of daylight
- o Autumnal Equinox September 23
  --same as vernal equinox
  --every latitude gets 12 hours of daylight
  --subsolar point the Equator
- o Winter Solstice December 22
  --subsolar point the Tropic of Capricorn 23.5° S
  --south of Antarctic Circle gets 24 hours of daylight



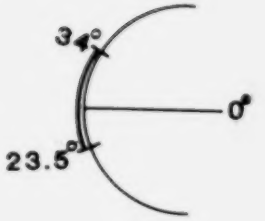


- o The amount of insolation received at any latitude depends on the daylength and the angle at which the sun's rays strike the earth
- o The higher the sun angle the more intense the insolation is because the energy is concentrated in a smaller area--it's more direct. The solar radiation travels through less atmosphere which tends to absorb, disperse and reflect solar radiation.
- o The lower the sun angle the less intense the insolation is because the energy is distributed over a larger area. The solar radiation travels through more atmosphere.
- o To find the noon sun angle (solar altitude) use the equation
  90^{o} - arc distance = noon sun angle
- o The arc distance is the number of degrees between the latitude of the subsolar point and the latitude in question.

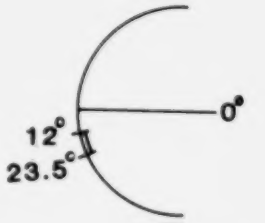
Example: Los Angeles 34° N
What is the solar altitude on summer solstice (June 21)?
Subsolar point on June 21 is 23.5° N
The arc distance is 34 - 23.5 = 10.5
90 - 10.5 = 79.5° (above the southern horizon)



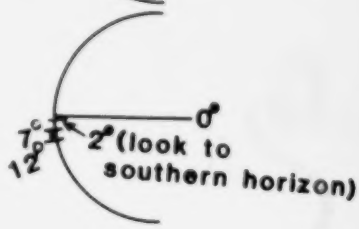
Example: Los Angeles 34° N
What is the solar altitude on winter solstice (December 22)?
Subsolar point on December 22 is 23.5° S
The arc distance is 34 + 23.5 = 57.5
90 - 57.5 = 32.5° (above the southern horizon)



Example: Lima, Peru 12° S
What is the solar altitude on winter solstice (December 22)?
Subsolar point on December 22 is 23.5° S
The arc distance is 23.5 - 12 = 11.5
90 - 11.5 = 78.5° (above the southern horizon)

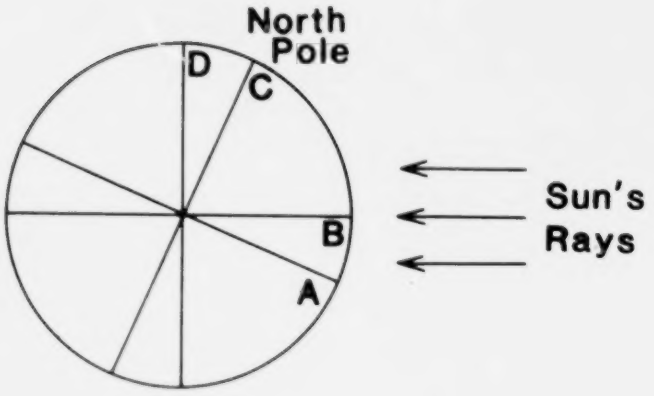


Example: Lima, Peru 12° S
What is the solar altitude on March 3?
From an analemma--the subsolar point is 7° S
The arc distance is 12 - 7 = 5
90 - 5 = 85° (above the northern horizon)



Version A

1. Which of the lines marked on Figure 1 represent the following?



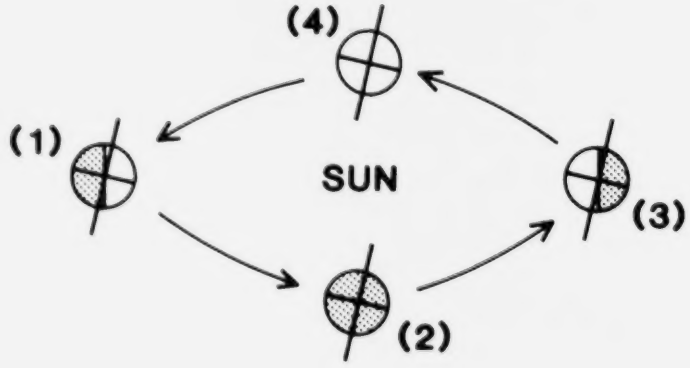
Equator ____

Polar Axis ____

Circle of Illumination ____

Plane of the Ecliptic ____

2. Figure 2 shows the position of the earth with respect to the sun at various times of the year.



Which position represents:
(a) Autumnal Equinox_____
(b) Summer Solstice_____
(c) Winter Solstice_____
(d) Vernal Equinox_____
Longest length of day in southern hemisphere _____
Most southerly point of illumination at position 2 _____

3. Give the name and significance of each of the following lines of latitude.

(a) 23.5° N _____

(b) 66.5° S _____

(c) 66.5° N _____

(d) 23.5° S _____

Version B

1. Convert the following measurements. Show your work neatly, please.

100^{o} of latitude to m	Answer:	_____m
7 miles to km		_____km
Your height to m		_____m
95^{o} F to ^{o}C		_____^{o}C
12 gallons to liters		_____liter

2. What are the first and last dates of the period of the year during which the nights are longer than the days (in the northern hemisphere)?

_____ through _____

3. How often, in one year, is the sun directly overhead (at noon) at the following latitudes?

Honolulu, Hawaii, 21.4^{o}N	_____
Los Angeles, California, 34^{o}N	_____
Fort Yukon, Alaska, 66.5^{o}N	_____
Trinidad, Bolivia, 0^{o}	_____

4. What percent of the globe is illuminated (in daylight) on June 21? _____%

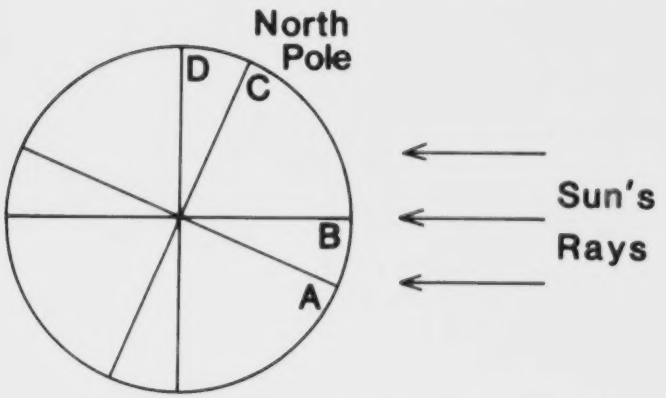
5. As we vary the angle of strike of the sun's rays with the earth's surface, what two effects act to increase or decrease the intensity of the solar radiation? (Please keep your answers brief.)

One effect:

The other effect:

Version C

1. Which of the lines marked on Figure 1 would represent the following?



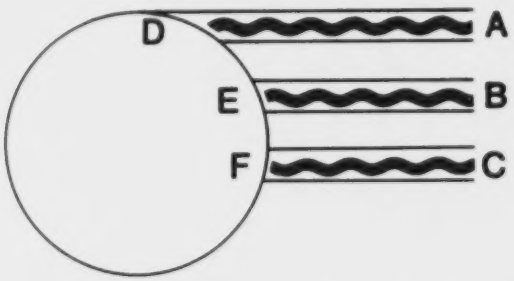
Equator ____

Polar Axis ____

Circle of Illumination ____

Plane of the Ecliptic ____

2. Figure 2 shows three equal amounts of solar energy (A, B & C) striking the earth at different latitudes.



(a) Which bundle travels the longest through the absorbing, scattering, and reflecting atmosphere? _____

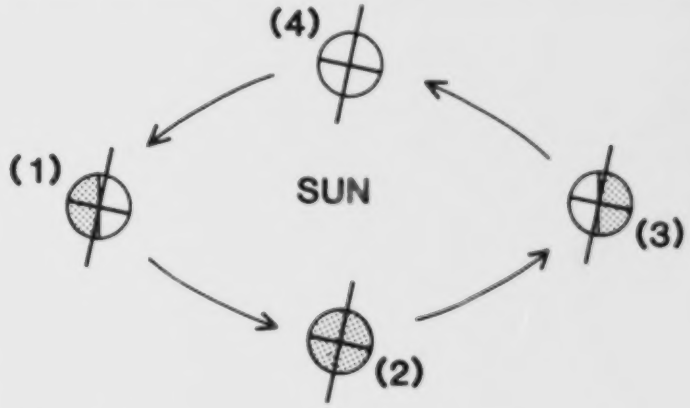
(b) Give two reasons why a square meter of land would receive more solar energy at F than at D. _____

(c) Figure 2 is drawn as though it is an equinox. What is the length of day at D, E, and F? _____

3. What is the angle measured from the earth's axis to the plane of the ecliptic? _____

4. The earth is furthest from the sun on July 4. This day is called _____.

5. Figure 3 shows the position of the earth with respect to the sun at various times of the year.



Which position represents:

(a) Autumnal Equinox _____
(b) Summer Solstice _____
(c) Winter Solstice _____
(d) Spring (or Vernal) Equinox _____
(e) Longest length of day in southern hemisphere _____
(f) What is the most northerly point of illumination at position 3? _____
(g) What is the most southerly point of illumination at position 2? _____
(h) Latitude 76°S would receive _____ hours of daylight at position 1.
(i) At position 1, how many degrees north of the Equator are the sun's rays striking the earth perpendicularly? _____ What is this line called? _____

SUN ANGLES (Show all calculations)

The height of the sun above the northern or southern horizon at noon can be calculated by the equation: noon sun angle = 90 - arc distance.

The arc distance is the difference, in degrees, between the latitude in question and the latitude where the sun's rays strike perpendicularly (called the sub solar point). For example, on June 21, the sub solar point is 23.5° N. The noon sun angle at 33.5° N on that day is 90 - (33.5 - 23.5) = 90 - 10 = 80°. The noon sun angle at 33.5° S is 90 - (33.5 + 23.5) = 90 - 57 = 33°.

6. What is the noon sun angle at 50° N on the winter solstice? _____

7. What is the noon sun angle at 50° N on the autumnal equinox? _____

8. Which location would receive more solar radiation on September 21 (assuming no clouds at either place)--Sao Paulo, Brazil (24°S) or Los Angeles (34°N)? _____

UNDERSTANDING TOPOGRAPHIC MAPS

3. CONTOUR AND TOPOGRAPHIC MAPS

Contour maps and the use of contour maps are an essential component of any physical geography course, yet many students have great difficulty initially arriving at a sound understanding of such maps. In addition to learning the various symbols found on such maps and the information relating to orientation and positional information, it is imperative that students develop the capacity to three dimensionally interpret the information contained on the sheets before them. To that end, the use of models and photographs is encouraged. Once the basic concepts are grasped, students tend to progress rapidly in developing their interpretative skills.

The exercises which follow attempt, in different ways, to make the students aware of the information available from contour maps and also increase their confidence when using the maps.

Topics to cover

Contour lines

Topographic profiles

Vertical exaggeration

Representative fraction

USGS topographic symbols

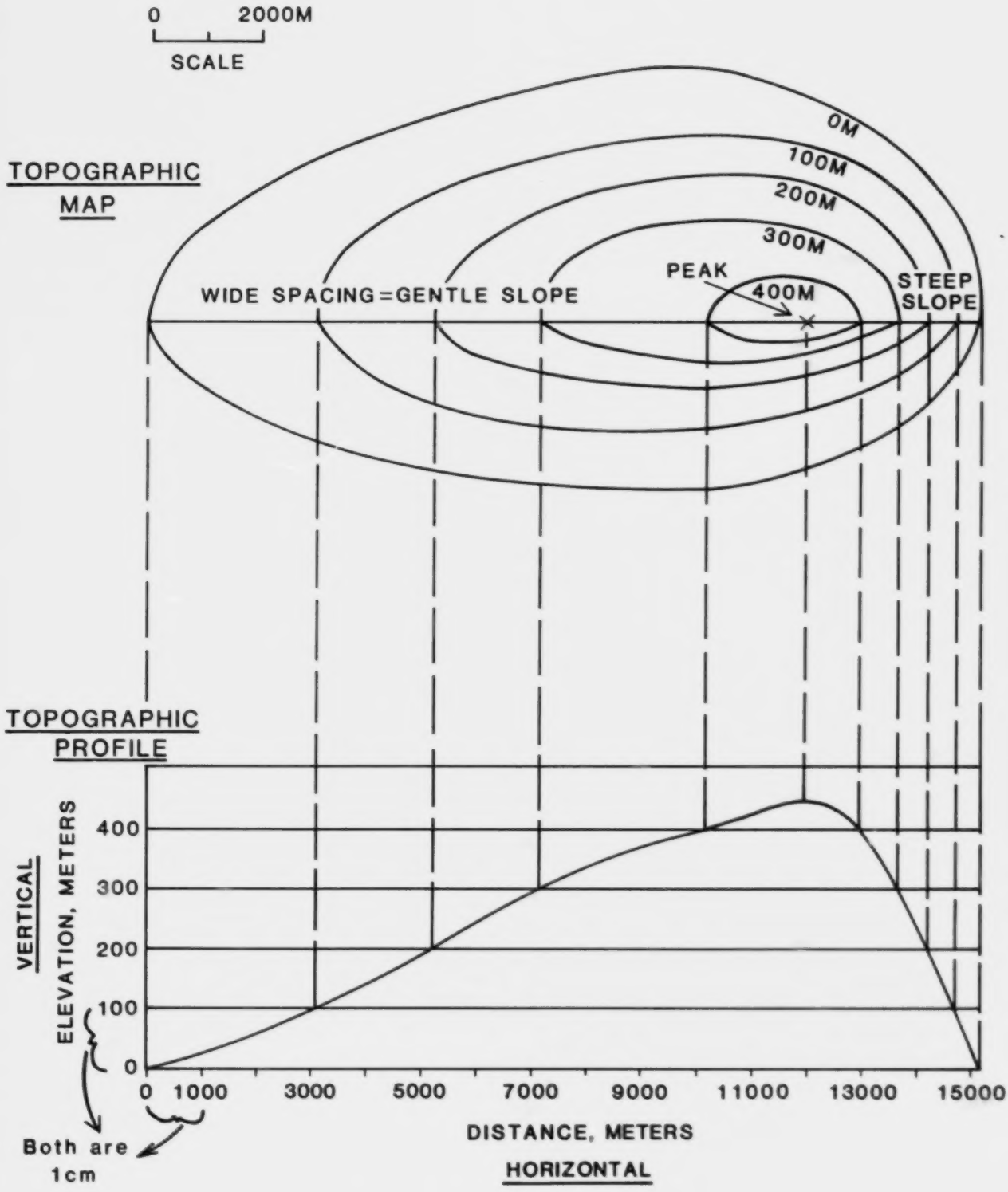
A more detailed discussion of specific topics

A contour line is drawn on a map through points of equal elevation above a datum plane (usually mean sea level). The following rules for using contours should be followed:

- The value of a contour line is a multiple of the contour interval. Every fifth (usually) contour is darker and is called an index contour.
- Contour lines never touch or cross one another. Therefore, they distinguish points of higher elevation from points of lower elevation. (The exception to this rule is when a vertical wall is being portrayed.)

- Every contour closes on itself, either within or beyond the limits of the map. In the latter case, the ends of the contour will extend to the edge of the map.
- Uniformly spaced contours indicate a uniform slope.
- If spaced far apart, contour lines indicate a gentle slope; if closely spaced, they represent a steep slope.
- Along a stream course contours form a "V," with the base of the V pointing upstream.
- Along a ridge they form a "V" also, with the base of the V pointing down the ridge.
- A contour which closes within the limits of the map represents a hill or a rise.
- The elevation of a hilltop, unless otherwise noted, is expressed as an intermediate value, somewhere between the value of the highest contour below the peak and the value of the next higher contour above it (not shown on the map).
- A depression is represented by closed contours which are hachered on the side toward the depression.
- The elevation of a depression contour is the same as that of the adjacent lower contour, unless otherwise marked.
- Topographic profiles: side view of a line on the landscape.
- Vertical exaggeration: shows how much the vertical scale has been "stretched" relative to the horizontal scale on a topographic profile. If one inch on the horizontal scale equals 800 feet and one inch on the vertical scale equals 200 feet, then V.E. = H/V = 800/200 = 4.
- Compasses and magnetic declination.
- Representative fractions.
- Stream gradients: elevation drop from source to mouth (or a portion) divided by length.
- Watershed boundaries: how to trace along a ridge to outline a drainage basin.

CONSTRUCTING A TOPOGRAPHIC PROFILE



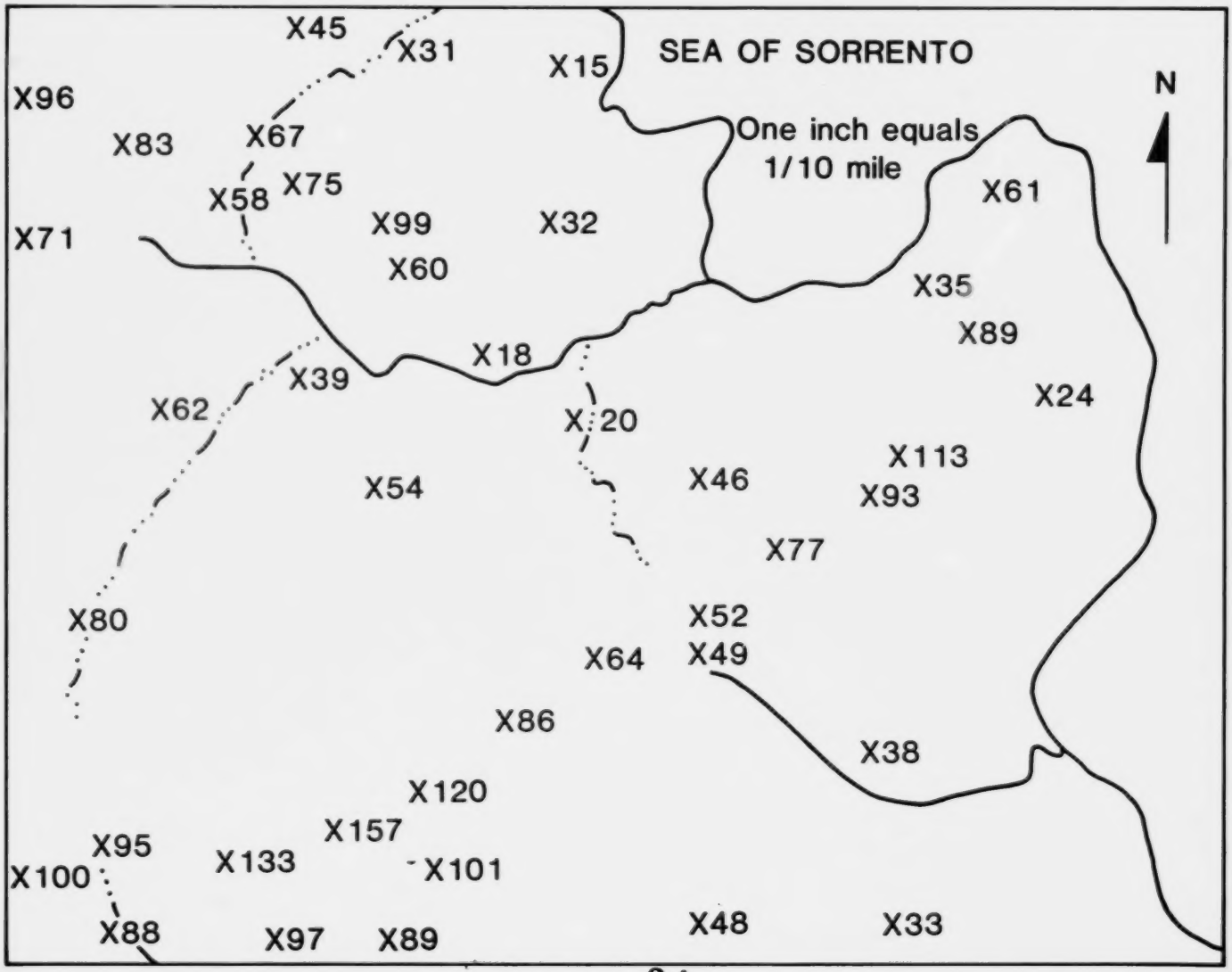
100M ON THE VERTICAL SCALE EQUALS 1000 METERS ON THE HORIZONTAL SCALE

VERTICAL EXAGGERATION = $\frac{H}{V} = \frac{1000}{100} = 10$

Version A

Topographic maps make use of the isohypse (contour line) to indicate elevations. Contours are lines connecting points of equal elevation above an accepted base level, usually mean sea level. They are drawn at a stated vertical distance (contour interval) which will vary with the ruggedness of the terrain, i.e., a large interval is chosen in areas of steep slopes, and a small interval is used in comparatively level areas. As slopes steepen, contour lines drawn at prescribed intervals appear closer together.

On the map below, plot and number each isohypse at ten foot intervals commencing from sea level. The final product must be in ink, although you are strongly urged to use pencil until satisfied that the contour lines are accurately drawn. Keep in mind the following points: (1) as summits or hilltops are approached, contour lines form enclosures; (2) all lines should either form enclosures or extend to the margin of the map; (3) isohypses bend upstream as they cross river valleys and downstream as they cross intervening ridges; and (4) contours never cross or merge with one another.



Version B

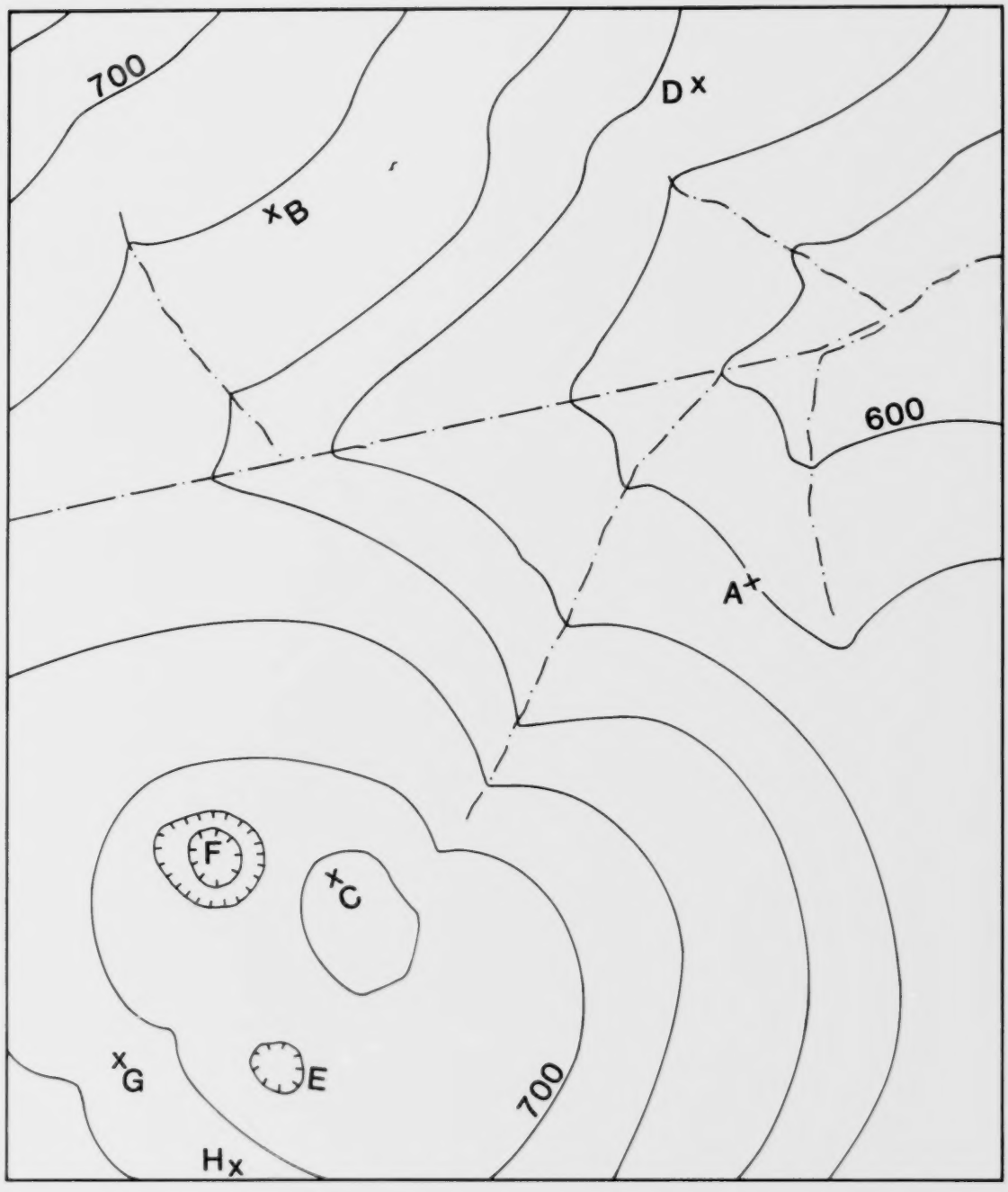
Referring to the topographic map of "Contourland":

1. What is the contour interval used on the map? _____
2. Give the elevation of the contour at Point A. _____
3. Give the elevation of Point B. _____
4. What is the elevation of Point D? _____
5. Estimate the elevation at the summit (Point C). _____
6. Give the elevation of the depression contour at Point E. _____
7. Estimate the elevation of the bottom of the depression at Point F. _____
8. Is G on a ridge or a gully? _____
9. On the sheet provided, construct a topographic profile from Point H to Point D.
10. What is the vertical exaggeration of the profile you just drew? _____

From your map of Point Reyes:

1. What is the map scale, expressed as a representative fraction? _____
2. What is the contour interval? _____
3. What is the datum plane used for these contours? _____
4. The magnetic declination is? _____
5. When was this map most recently updated? _____
6. What are the geographic coordinates (latitude and longitude to the nearest minute) of Mount Wittenberg (about 4 km south-southwest of Point Reyes Station)? _____
7. What is the elevation of Black Mountain (about 4 km east-northeast of Point Reyes Station)? _____
8. Give the elevation of the unnamed mountain at (approximately) 38° 4' N, 122° 47' W. _____
9. Which mountain is steeper near the peak, Black Mountain or the one you found in Question 8? _____
10. If the scale of this map were 1:1,000,000, would it show more or less detail than is shown on this one? _____

CONTOURLAND

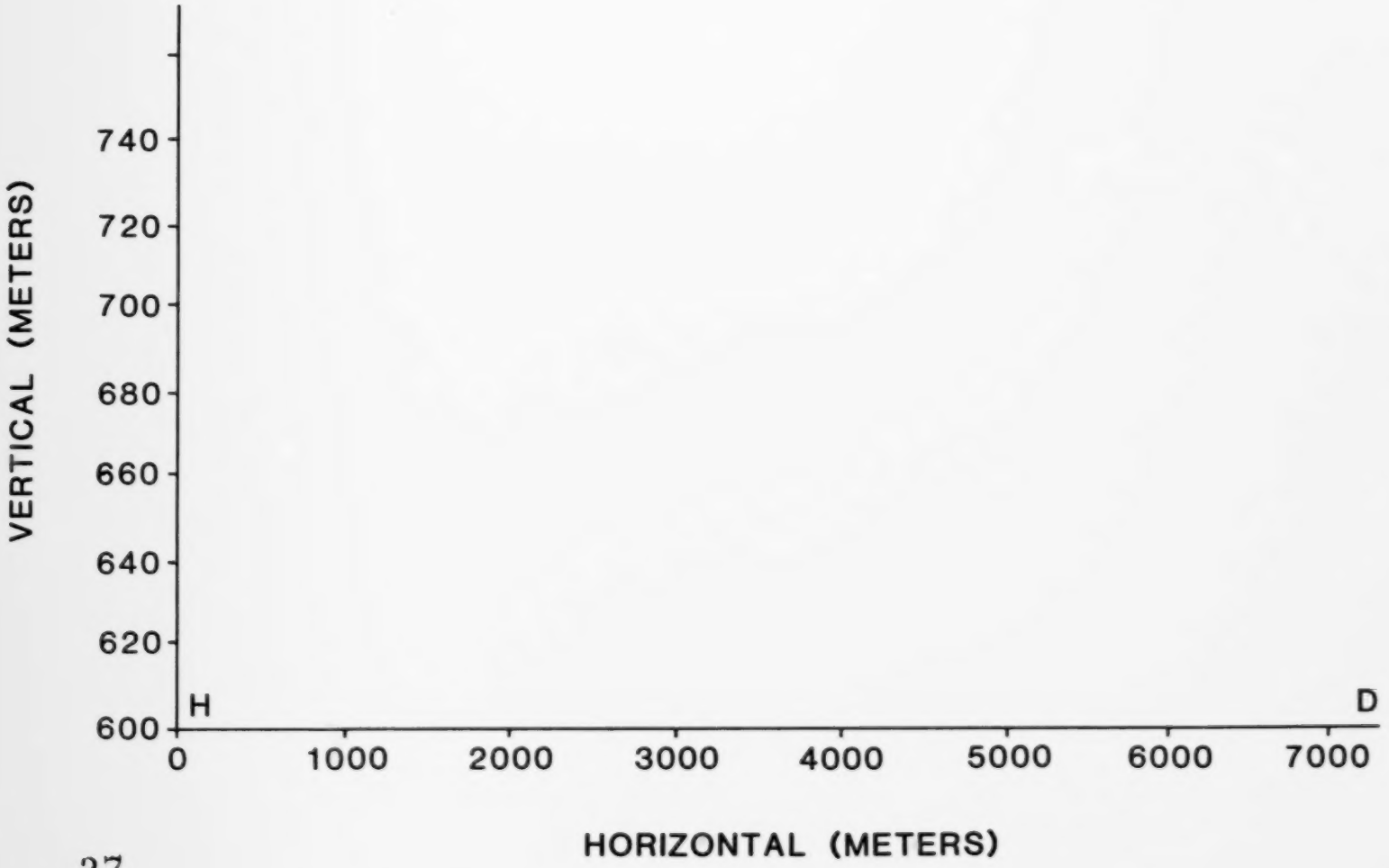


0 1000 2000 3000 4000 5000

METERS

(CONTOURS IN METERS)

Name_____


VERTICAL (METERS)
740
720
700
680
660
640
620
600
H
D
0
1000
2000
3000
4000
5000
6000
7000
HORIZONTAL (METERS)

37

38

Version C

To complete this exercise, you will need:

1. One copy of the Point Reyes quadrangle (topographic map)
2. A VERY SHARP PENCIL
3. One sheet of graph paper
4. One sheet of unlined paper (actually, notebook paper will suffice)
5. A ruler (either metric or English units)
6. Your eye glasses if you are far-sighted

General questions pertaining to Point Reyes:

1. What is the map scale expressed as a representative fraction? _____
2. Near what major California city is Point Reyes located? (See the location map along the bottom edge of the quadrangle.) _____
3. What is the contour interval on this map? _____
4. What is the datum plane used? _____
5. If you had a compass that was pointing toward the magnetic north pole, it would be pointing approximately _____ degrees _____ (east or west) of true north.
6. What are the geographic grid coordinates for the northwest corner of the map?
   Latitude _____
   Longitude _____

Topographic Profile

Follow the instructions carefully! Be neat and accurate! Staple when done!

1. Find the first "I" in Inverness Ridge.
2. Draw a faint straight line directly through and parallel to the "I".

3. Extend the line from the Pacific Ocean coast, over Inverness Ridge, through Tomales Bay, and up to the 400 foot index contour.
4. This is the line you are going to draw the topographic profile from.
5. If you have drawn the line correctly, it should go through the:
   "M" in McClures Ranch
   "d" in Lairds Lodge
   "v" in Cypress Grove
   "G" in R.R. Grade
6. Set your vertical scale on the graph paper to be approximately 320 feet to the inch, starting at 0 feet (sea level). Leave a bottom margin on the graph paper.
7. Now, follow the instructions on "The Topographic Profile" handout and draw your profile on the graph paper. Don't mark the depth contours in Tomales Bay; assume sea level across the bay.
8. Label Tomales Bay on your profile.
9. With a small arrow, mark the location of the stream.

10. Mark the slopes where vegetation can be found (the solid green on the map) with little vegetation symbols.

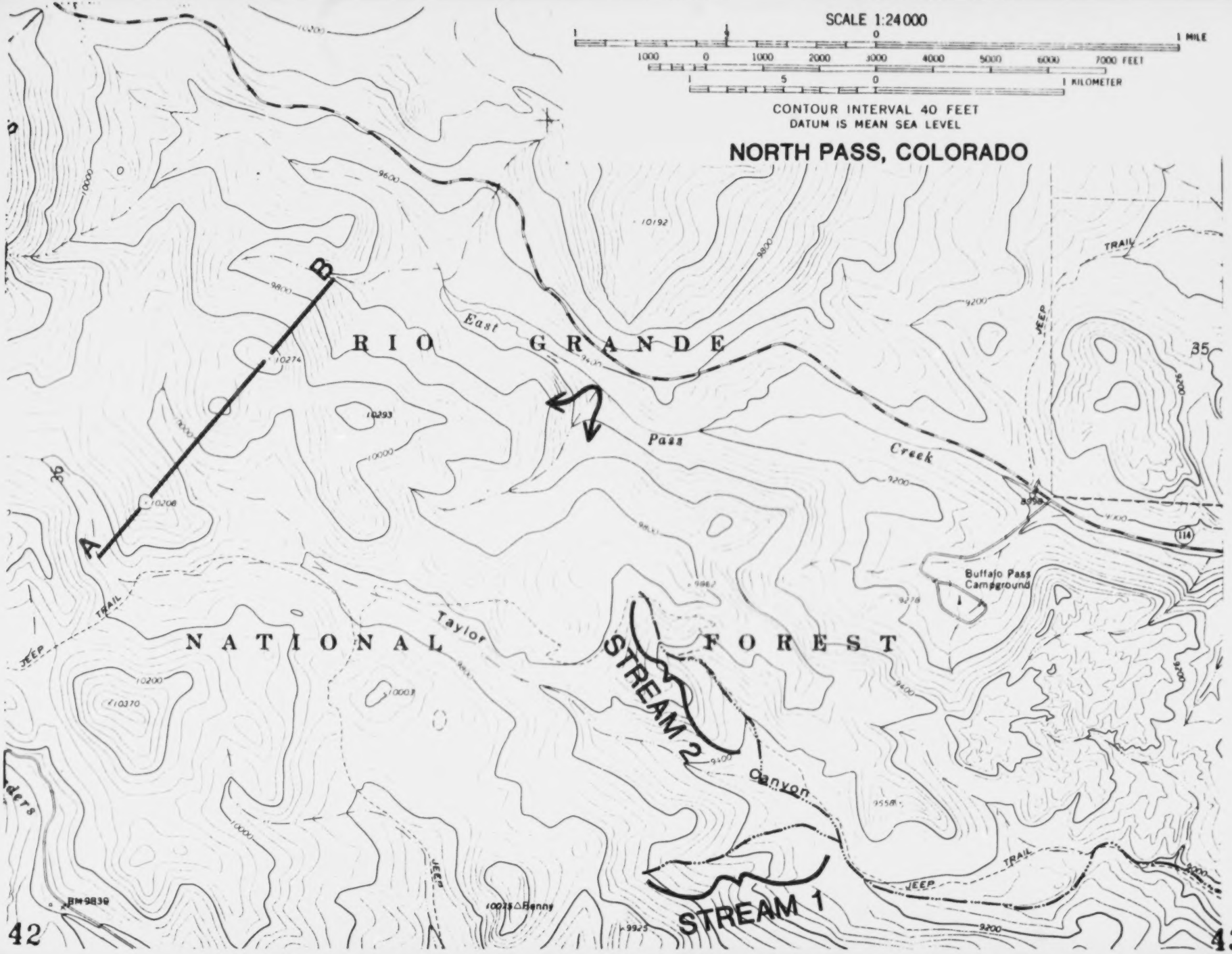
11. Which direction is this slope facing (northeast or southwest)? _____
12. Why would there be significant vegetation on this slope and not the other (referring to Question 11)? (Hint: think of sun angles--which slope receives more direct and therefore intense solar radiation--which slope would be drier? Be brief!) _____
13. What is the average gradient of the intermittent stream just north of Cypress Grove (measure the entire length of the stream)? _____ feet/miles.

Version D

POINT REYES: When you first look at any topographic map, there are several important pieces of information to look for. On the Point Reyes sheet you should see (and understand) that the scale is 1:62,500, the contour interval is 80 feet, the magnetic declination is 17.5°E, the map was drawn in 1954 and updated in 1968, and that this area is located near San Francisco.

What are the geographic grid coordinates (to the nearest minute) of the east end of Point Reyes (southwest part of the map, by "Chimney Rock")? _____ Find the same for Hog Island (between the words "Tomales" and "Bay" in the northwest part of the map). _____ Estimate the elevations of the following places: Coast Campground (north of the word "Bay" in Drakes Bay) _____. The point where the stream in Millerton Gulch is shown to change from intermittent to perennial (Millerton Gulch empties into the southern part of Tomales Bay, from the northeast) _____.

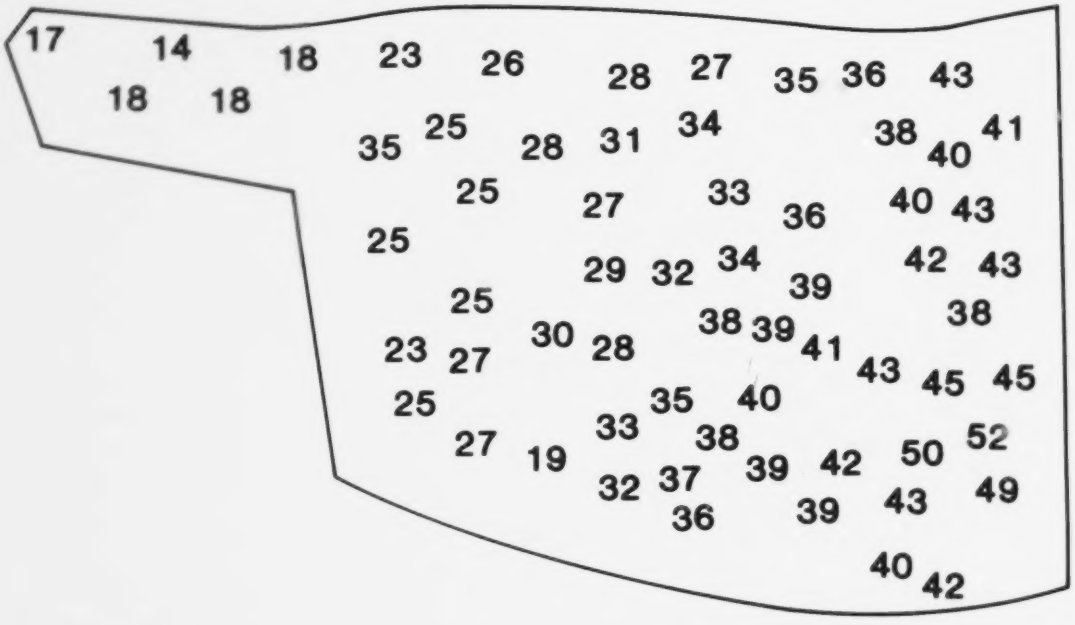
NORTH PASS: You have been given a copy of a portion of the North Pass, Colorado, topographic sheet. On that copy draw in the watershed boundary for the stream in the center of the map. This has been started for you--continue in the directions of the arrows and use a sharp pencil. On the graph paper draw a topographic profile of the line connecting Points A and B. Use a sharp pencil and remember--NEATNESS COUNTS! Your horizontal scale should be labeled in feet (this will not correspond with the grid on the graph paper) and the vertical scale should be 1 cm equals 200 feet (each little line equals 20 feet). The vertical exaggeration can be calculated--1 cm on the vertical scale is 200 feet, and 1 cm on the horizontal scale is about 700 feet; vertical exaggeration is H/V = 700/200 = 3.5. Your profile should include a title, labeled axes ("horizontal distance, feet" and "elevation, feet"), and the vertical exaggeration. Show the locations of the three streams and give the elevations of the three peaks (the map tells you the heights of two of them, estimate the elevation of the third). Estimate the gradients (in feet/miles) of Stream 1 _____ and Stream 2 _____. Which stream has the most constant gradient (i.e., a more uniform slope throughout its length)?_____ Show how you calculated the gradients here:



BEST COPY AVAILABLE

Version E

I. Isopleth mapping exercise:
An isopleth is a line connecting points of equal values. Below is a map of a county on which are given figures for annual precipitation at selected stations. From these figures, you are to draw isohyets (lines connecting points of equal precipitation) at 20", 30", 40", and 50" intervals. Extend the isohyets to the borders of the map. Use a pencil and turn in a finished, neat map.

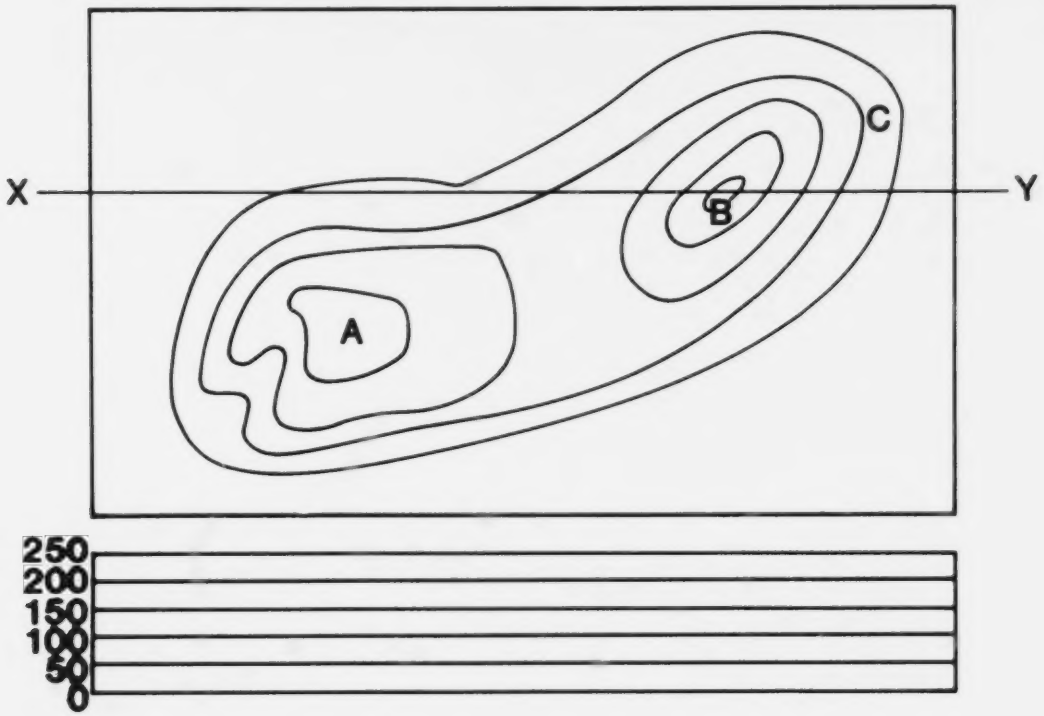


II. Map scale:
A map with a scale of about 1:75,000 is considered a large-scale map. A map with a scale on the order of 1:600,000 is considered a small-scale map. You are given two maps, map #1 with a scale of 1:50,000, and map #2 with a scale of 1:1,000,000.

(a)Which map would show the most detail? _____
(b)If both maps are printed on the same size sheet of paper, which map will show the greatest area? _____
(c)If you were planning a walking trip in the Santa Monica mountains, which map would be most suitable for planning your route? _____
(d)You are given a map of the marina at Marina Del Rey. You know from having measured the trip that it is exactly two miles from your parking space in a public lot to the small (but attractive) yacht you have secretly desired for the past three years. On the map, your parking space and the slip where the yacht is tied up are two inches apart. Expressed as a representative fraction, what is the scale of your map? _____

III. Below is a topographic map of an island. The contour interval on this map is fifty feet.

(a) What is the elevation at Point A on the map? Greater than _____ feet but less than _____ feet.
(b) What is the elevation at Point B? _____
(c) What is the elevation at Point C? _____
(d) If you were standing at Point A, could you see your friend standing at Point B? _____
(e) If you were standing at Point A, could you see your friend standing at Point C? _____



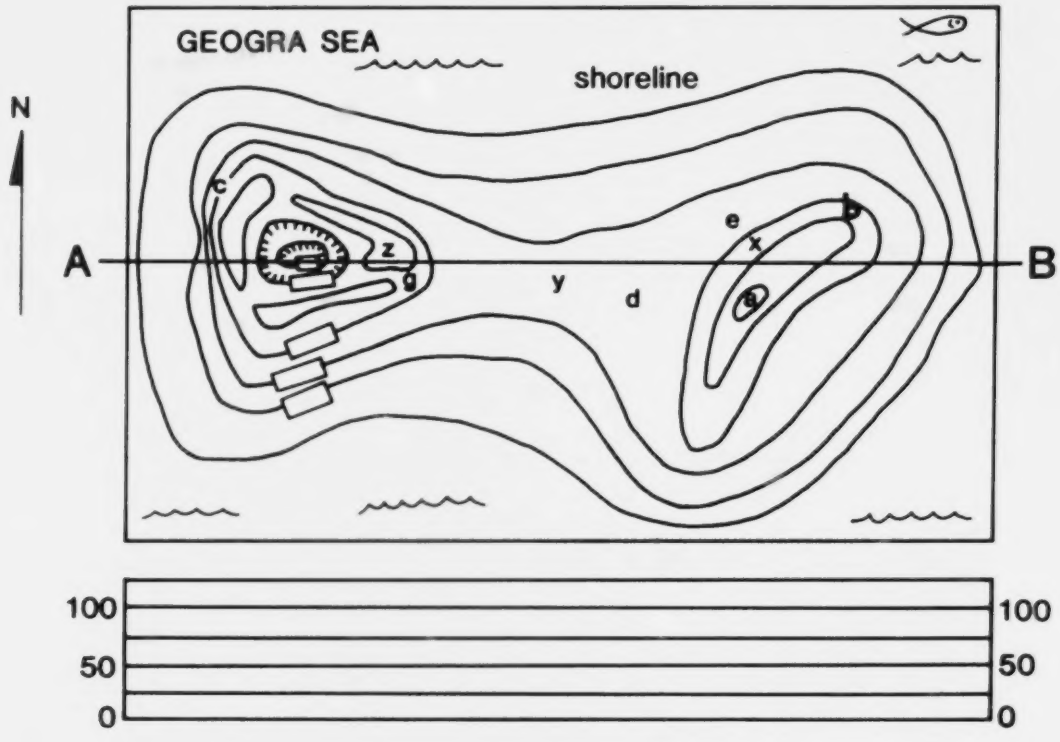
(f) On the graph above, sketch the topographic profile for line XY.

IV. Draw your own contour map:
In the space below, draw a contour map of an island. The scale of the map is one inch to one mile. The contour interval is twenty feet. The island is rectangular in shape, being four miles long in the east-west direction and one mile wide in the north-south direction. There is a circular hill on the eastern half of the island. Its summit is 130 feet high. This hill is very steep on its northern side. The southern slope of the hill is very gentle. The highest elevation on the western half of the island is eighteen feet.

Version F

1. The topographic map below represents Renwick Island in the Geogra Sea. The contour interval is twenty-five feet. The map scale is one inch equals 1000 feet. Place the correct elevations of each contour line in the dashed boxes.

2. What is the elevation at Point "x"? Greater than _____ feet but less than _____ feet; at Point "y"? _____; at Point "z"? _____



3. In the space above, sketch a topographic profile for line AB.

4. Indicate by the letter "S" on the contour map, the area with the steepest slope.

5. If you stood at Point "b", could you see your upright teacher at Point "c"? _____ Why?

6. If you stood at Point "b", could you see your upright teacher at Point "d"? _____ Why?

ATMOSPHERIC PROCESSES AND WEATHER PATTERNS

4. SOLAR ENERGY

The variability in the distribution of solar radiation received at the earth's surface is one of the fundamental factors affecting many, if not most, processes which physical geography deals with. In addition to the terminology developed to deal with this exceedingly complex process, it is essential that the student understand both the concept of energy budgets and, at least in an elementary way, the basic energy balance equation. This introduction to energy budget climatology need not be a quantitative nightmare for the mathematically naive. If an effort is made to deal only with the basic procedures and processes involved in order to provide the student with a sound grasp of the principles at work, then there should be a reasonable success rate.

In addition to a somewhat traditional energy balance exercise, a computer-based exercise has also been included. I have had considerable success in using such a computer radiation exercise in our introductory physical geography course. The use of such an exercise serves several purposes:

1. It introduces students who are often computer illiterate to the use of such equipment in problem solving.
2. It demonstrates how computers may be used to process data and solve problems in geographic research.
3. It begins to give students a sense of how models and, in particular, computer-based models, are used in physical geography.

The exercise and driving main program were written for use in UCLA's 3033 IBM main frame with students working from IBM 3278 terminals using WYLBER. The program should be readily adaptable to other large systems and minicomputers.

In order to facilitate the use of the computer radiation exercise, the following have been included: (1) a detailed description of the program; (2) a program listing; (3) a set of terminal and operating instructions given to each student; and (4) a copy of the exercise itself.

It must be stressed that the exercise is intended for students who do not have any experience with computers. A substantial component of the instruction time available is therefore taken up with simply learning to turn on the terminal and begin the operation of entering instructions. Each student is able to enter his own set of coordinates and the net result is the production of a computer printout containing radiation values for that location at different times of the year.

Topics to Cover:

Insolation--variation over globe
(intensity and day length)

Energy budget equation
insolation--Q (direct solar radiation) and q (diffused solar radiation)
albedo--a (1.0 = complete reflection; 0 = complete absorption)
outgoing longwave--$I\uparrow$ (radiated from surface)
counterradiation--$I\downarrow$ (radiated from sky--longwave)

$(Q + q)(1 - a) + I\downarrow - I\uparrow$ = net radiation
= energy to be distributed within the system

Net radiator distributed by:
Conduction--heat transferred through solids
Convection--heat transferred through liquids and gases
Latent heat--transferred through evaporation of water
Net radiation = conduction + convection + latent heat
Humid areas--high latent heat
Arid areas--high convection

A more detailed discussion of specific concepts

We are essentially interested in the disposition of the solar energy which reaches the earth's surface.

Solar Energy: Solar energy is one example of electromagnetic radiation. The sun emits energy over a range of wave lengths, the quantity and wave lengths being determined by the temperature of its surface. We call solar radiation "shortwave" because its wave lengths are shorter than the earth's radiation, which is referred to as "longwave." (The earth is cooler than the sun and so emits less energy but with longer wave lengths.)

One way of measuring solar radiation is with the unit "langley" which equals one

calorie of energy per square centimeter. At the top of the earth's atmosphere, approximately 1.94 langleys/min. arrive at that point directly facing the sun. This is the "solar constant." As the energy travels through the atmosphere, it can be reflected, absorbed, or scattered by particles. Some of the shortwave radiation which is scattered still reaches the surface ("diffused solar radiation"), so the total reaching the surface is direct beam (unaltered) solar radiation, Q, plus diffused radiation (q).

At the surface, some of the (Q + q) is reflected away (this is the "albedo," a, and is measured as 1.0 = complete reflection, and 0.0 is no reflection). If the albedo is .3, then the amount absorbed is 1 - .3 = .7, or 70 percent. Inputs of solar energy, then, are (Q + q) (1 - a).

Now we look at longwave radiation. The earth's surface radiates longwave energy ($I\uparrow$ for infrared radiation going up), and so do the particles in the atmosphere ($I\downarrow$ for infrared radiation coming to the surface). Now we have the basic components of the electromagnetic portion of the energy budget equation $(Q + q)(1 - a) + I\downarrow - I\uparrow$ = Net radiation.

Net radiation is, therefore, the difference between incoming and outgoing radiation. Net radiation is disposed of in three ways: conduction, convection, and latent heat of vaporization. Conduction is heat transferred molecule by molecule through a solid. Convection is the transfer of heat by mixing molecules in a fluid (water or air). Latent heat deals with the transfer of energy as a result of evaporation, condensation, or sublimation of water.

Examples of Energy Budgets

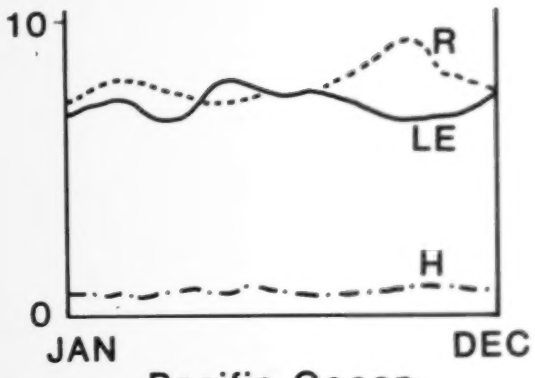
1. There is a surplus of net radiation near the Equator and a deficit near the poles. Global circulation is a physical effort to balance this inequality. Convection and latent heat are the major processes involved.

2. Most solar collectors are designed to maximize net radiation and dispose of it through conduction and convection into a heating system.

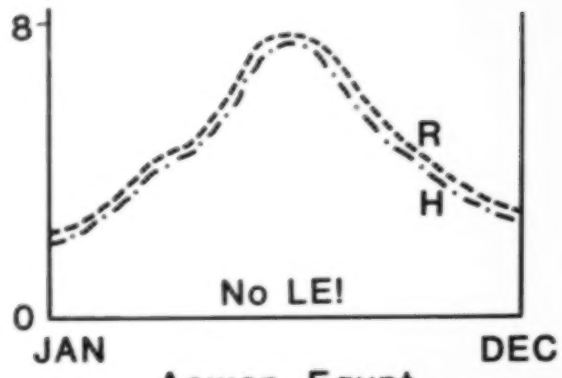
3. Arid areas have little water to evaporate, so net radiation is mostly dispersed by convectional heating of the air and conduction into the ground.

CLIMATOLOGICAL ASPECTS OF HEAT BALANCE-- A LOOK AT THREE DIFFERENT LOCATIONS

The vertical scale units are kilogram-calories per cm^2 per month.

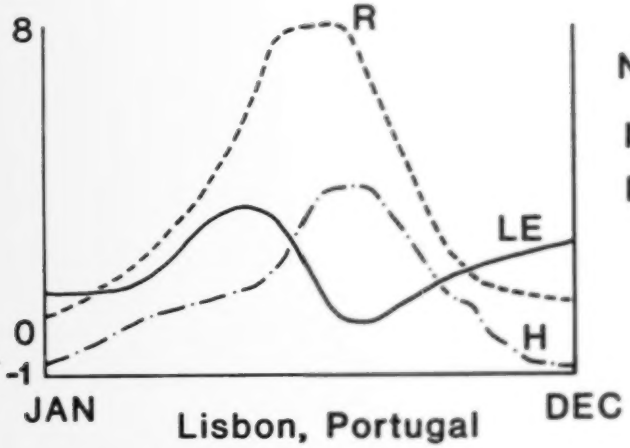


Pacific Ocean
(Equatorial)
0° lat., 150°E



Aswan, Egypt
(Tropical Continental)
24°N, 33°E

(Almost all of the energy goes to heat the air)



Lisbon, Portugal
(Subtropical)
west coast of the continent
39°N, 9°W

Note:

In summer, H > LE

In wet winter, LE > H

R = Net Radiation ----------
H = Heating — · — · —
LE = Latent Energy ————
C = Convection ·····

The above is the use of energy budget diagrams to depict climate of an area. G was so minor in course of a year, that it was not included.

Version A

I. Insolation Curves

Below are yearly data of insolation. All values (langleys/day) are for the fifteenth day (24 hour period) of each month at the various latitudes at sea level.

LAT	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
0°	480	512	530	518	500	485	490	520	550	547	507	475
45°N	152	245	367	495	582	625	605	537	415	285	180	130
90°N	0	0	0	155	482	667	610	303	27	0	0	0

Plot the data on graph paper, with the months on the X-axis and insolation (langleys/day) on the Y-axis. Be sure to label the axes and the three curves (one for each latitude) you draw connecting the data points.

Answer the following questions about the insolation curves.

1. Identify the highest and lowest values for each latitude and month when they occur.

	HIGH	MONTH	LOW	MONTH
0°	_____	_____	_____	_____
45°N	_____	_____	_____	_____
90°N	_____	_____	_____	_____

2. Which latitude exhibits the greatest yearly range of insolation? _____

3. Why is the range greatest at this latitude? (Your explanation should include consideration of duration and intensity of insolation.) _____
_____
_____
_____

4. Which latitude exhibits the smallest yearly range of insolation? _____

5. Why is the range smallest at this latitude? _____
_____
_____
_____

6. Why are there two maxims (two peaks) on the 0° latitude curve?
_____
_____
_____

7. When the highest insolation value is reached at 90° N, what is the insolation at 0°? _____ langley/day

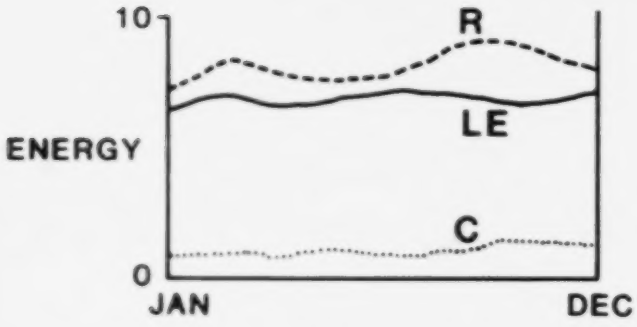
8. What is the major factor which accounts for this difference? (referring to #7

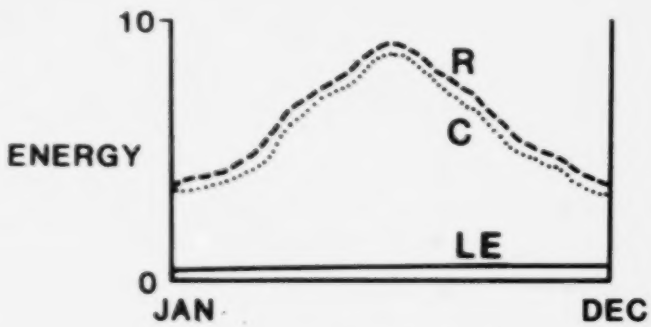
above) _____

9. Photosynthesis, and thus plant growth, is dependent on the amount of solar radiation received by a plant. Cabbage grows larger in Alaska than in California. Look at the insolation curves you drew and explain this solely in terms of duration and intensity of solar radiation. (Other factors are involved, of course, but ignore them for now.)

II. Energy Budget Graphs

Examine the two energy budget graphs below. (Conduction (G) is not included because values were insignificantly small at both locations.)





R = Net Radiation ----------
H = Heating —·—·—·—
LE = Latent Energy ————
C = Convection ·····

Answer the following questions about the graphs and their locations.

1. Which location is probably over a large body of water (i.e., the ocean)?
_____

2. How do you know this? (Hint: compare H and LE values.)
_____

3. Which location is probably in an arid region? _____

4. Again, how do you know? _____
_____

III. You are designing a solar collector. Next to each term put a + if you want to maximize this factor and a - if you want to minimize it.

___ (a) insolation
___ (b) counterradiation
___ (c) albedo
___ (d) outgoing longwave radiation

Version B

Description of Computer Program

This description makes references to the program listing on white and green bar computer paper. The line numbers in the left margin of the listing will serve as a guide. Lines in the program that start with a "C" are comments--they do not influence the program.

Lines 1000 to 10,000 are comments regarding the simplifications implemented. Note that this program is far from the current state of the art.

Lines 12,000 to 18,000: this is where the student is asked for the latitude assigned. Following that are initializations of many variables (lines 21,000 to 35,000). In reality, these variables are changing throughout the day.

The solar constant is then calculated:

line 37,000: $S = \frac{E_s}{4d^2}$ $\quad E = 5.6 \times 10^{27} \quad \frac{cal}{min}$

This is a simple geometric relation; dividing the energy output of the sun by the surface area of a sphere whose radius is equal to the average earth-sun distance.

Down to line 45,000 are more initial values, as well as conversion of degrees to radians (computer trigonometry is always performed in radians).

Lines 46,000 to 56,000 initialize the values for the subsolar point and radius vector for the seasons. The radius vector is used to express the actual earth to sun distance:

radius vector $\quad V = \frac{\text{actual earth-sun distance}}{\text{average earth-sun distance}}$

These values can be looked up in the Smithsonian Meteorological Tables.

Lines 60,000 to 68,000 calculate the hour angle. The earth is 360° around. It completes a rotation every twenty-four hours. Hence, in one hour, the sun "moves" 15°:

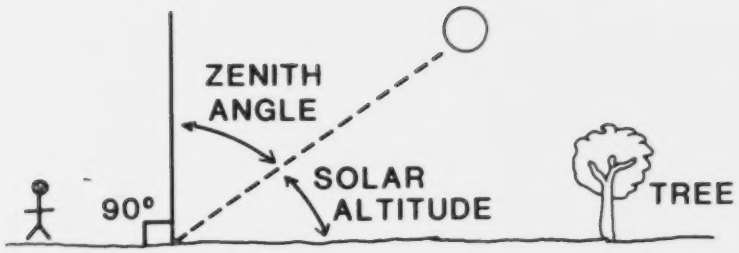
$$\frac{360^\circ}{24 \text{ hours}} = \frac{15^\circ}{\text{hour}}$$

The hour angle ranges from 0° at noon to 180° at midnight. This table shows hour angles through the day:

Hour:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18 ... 24
Hour angle:	165	150	135	120	105	90	75	60	45	30	15	0	15	30	45	60	75	90 ...180

The hour angle is used later in calculating the sun's position in the sky.

The distance (angle) from the horizon to the sun is known as the solar altitude. The complement of the solar altitude is the zenith angle (see next page):



Lines **69,000** to 71,000 calculate the zenith angle and its cosine using a trigonometric relation (law of cosines for spherical triangles--see Krieth & Kreider, Principles of Solar Engineering, for a good sketch explaining this):

$$\text{ZENITH} = \cos^{-1}\left[\sin(\text{latitude}) \cdot \sin(\text{subsolar point}) + \cos(\text{latitude}) \cdot \cos(\text{subsolar point}) \cdot \cos(\text{hour angle})\right]$$

A slight digression: at noon the hour angle = 0. Since cos (0.) = 1 the equation is simplified. Applying an identity for trigonometric products simplifies it yet further:

$$\cos(\text{Zenith}) = \sin(\text{lat.}) \cdot \sin(\text{SSP}) + \cos(\text{lat.}) \cdot \cos(\text{SSP})$$

$$= 1/2 \cos(\text{lat} - \text{SSP}) - 1/2 \cos(\text{lat} \,\&\, \text{SSP}) + 1/2 \cos(\text{lat} - \text{SSP}) + 1/2 \cos(\text{lat} \,\&\, \text{SSP})$$

$$= \cos(\text{lat} - \text{SSP})$$

Better yet, Zenith = lat - SSP. Recall from the previous sketch that:

Zenith angle & solar altitude = 90°.

So we can easily calculate the noon solar altitude (NSA):

$$\text{NSA} = 90^{\circ} - (\text{latitude} - \text{subsolar point})$$

Back to the program. Line 73,000 calculates the amount of solar radiation falling on a horizontal surface on the top of the earth's atmosphere (no atmospheric attenuation):

$$QS = \frac{\text{solar constant}}{(\text{radius vector})^2} \cdot \cos(\text{zenith})$$

Lines 74,000 to 80,000 deal with the solar azimuth. The azimuth is the "bearing" of the sun. The range of the azimuth is 0-360°, with due south = 0°:

$$\text{Solar azimuth} = \cos \quad \frac{\sin(\text{lat}) \cdot \cos(\text{zenith}) - \sin(\text{SSP})}{\cos(\text{lat}) \cdot \sin(\text{zenith})}$$

0°=S
90°=W
180°=N
270°=E

Consult Kreith for the derivation of the above.

Line 88,000 checks to see if the sun is below the horizon; if so, solar radiation is set to zero (night), and the next group of calculations is skipped.

Thus far, the program has been deterministic (mainly just mucking about with trig). Lines 89,000 to 100,000 deal with atmospheric attenuation--the absorption, reflection, and transmission of solar radiation. These processes are not fully understood, hence empirical approximations are required. Since empirical relations cannot be physically derived, we'll look at the factors involved but not the actual equations.

Optical air mass: When the sun is directly overhead, its rays travel through the least possible atmospheric thickness. When the sun is low in the sky, the rays travel through more atmosphere. Optical air mass = 1 when the sun is directly overhead, and is = 1 and increasing, the lower the sun is in the sky. The program first calculates this at sea level, then adjusts for the elevation of the station.

Barometric pressure: The greater the elevation of the station, the less atmosphere there is above it. Barometric pressure for the station elevation is used as a measure of atmospheric mass above.

Precipitable water vapor: Moisture in the air attenuates solar radiation. This tells us how much water vapor is in a column of unit area extending from station elevation to the top of the atmosphere.

Transmissivity: A function of the above factors, as well as dust, air pollution, aerosols, etc. Transmissivity varies inversely to atmospheric attenuation.

The effects of transmissivity and attenuation by clouds are incorporated in the following equation (line 103,000) which calculates direct beam solar radiation falling on a horizontal surface:

$$Q_{horizontal} = QS \cdot TZ \cdot (1 - (1-C) \cdot N)$$

(QS: top of atmosphere; TZ: transmissivity; C: cloud type; N: cloud density)

This gives us Q from the expression (Q + q). To find diffuse solar radiation (q), another empirical equation is used (line 105,000):

$$q_{horizontal} = (0.15 + 0.85 \cdot N) \cdot Q_{horizontal}$$

The two components are then summed (line 107,000) to give us total solar radiation falling on a horizontal surface:

$$(Q + q)_{horizontal} = Q_{horizontal} + q_{horizontal}$$

The output is then printed.

References

Terjung, W. H., and O'Rourke, P. A.: Outline of Boundary-Layer Climatology Methods and Analyses, 1978.

Kreith, F., and Kreider, J. F.: Principles of Solar Engineering, 1978.

Program listing

```
00397000  C*JOB
00398000  C  THIS FORTRAN PROGRAM CALCULATES THE HOURLY VALUES OF SOLAR RADIATION
00399000  C   FALLING ON A HORIZONTAL SURFACE AT ANY LATITUDE ON THE WINTER
00400000  C   SOLSTICE, VERNAL EQUINOX, AND SUMMER SOLSTICE.  THIS PROGRAM IS AN
00401000  C   ADAPTATION OF A PROGRAM WRITTEN BY PROFESSOR W. H. TERJUNG, UCLA
00402000  C   GEOGRAPHY DEPARTMENT.  FOR TEACHING PURPOSES THE PROGRAM HAS BEEN
00403000  C   HIGHLY SIMPLIFIED AND USES SOME UNREALISTIC AND/OR OBSOLETE
00404000  C   ASSUMPTIONS.  STUDENTS INTERESTED IN STATE OF THE ART SOLAR RADIATION
00405000  C   AND/OR ENERGY BUDGET MODELS SHOULD CONSULT DR. TERJUNG OR ENROLL IN
00406000  C   GEOGRAPHY 104, CLIMATOLOGY.
00407000        REAL I, LAT, MZ, N, MO, LATDEG
00408000  C PROMPT USER FOR LATITUDE
00409000        WRITE (6,100)
00410000   100  FORMAT (' TYPE THE LATITUDE ASSIGNED TO YOU'./.
00411000       &          ' >>     BE SURE TO USE A DECIMAL POINT          <<'./.
00412000       &          ' THEN HIT THE ENTER KEY')
00413000  C READ LATITUDE
00414000        READ (5,*) LAT
00415000  C SAVE DEGREES VALUE OF LATITUDE BEFORE CONVERSION TO RADIANS
00416000        LATDEG = LAT
00417000  C VAPOR PRESSURE IN MB - FOR SIMPLICITY SET TO A CONSTANT VALUE,
00418000  C   BUT IS UNREALISTIC FOR THE RANGE OF LATITUDES ASSIGNED
00419000        EA = 25.0
00420000  C DUST-HAZE EFFECT (DIMENSIONLESS)
00421000        D = 0.9
00422000  C CLOUD TYPE (0.85 = CIRRUS) (DIMENSIONLESS)
00423000        C = 0.85
00424000  C CLOUD DENSITY (0.1 = ONE TENTH OF SKY COVERED) (DIMENSIONLESS)
00425000        N = 0.1
00426000  C ENERGY OUTPUT OF THE SUN = 56 * 10**26 CAL/MIN
00427000        ES = 56.0E+26
00428000  C PI
00429000        PI = 3.1416
00430000  C MEAN EARTH-SUN DISTANCE = 1.5 * 10**13 CM
00431000        DBAR = 1.5E+13
00432000  C CALCULATE SOLAR CONSTANT IN CAL/CM**2 MIN
00433000        S = ES / (4.0 * PI * (DBAR**2))
00434000  C CONVERSION FACTOR FOR DEGREES TO RADIANS
00435000        RAD = 0.01745
00436000  C ASSUME SITE ELEVATION OF 500 FEET
00437000        ELEV = 0.5
00438000  C CONVERT LATITUDE TO RADIANS
00439000        LAT = LAT * RAD
00440000  C INITIALIZE VALUE OF RADIATION RECEIVED ON HORIZONTAL SURFACE
00441000        QAQHOR = 0.0
00442000  C VALUES FOR WINTER SOLSTICE
00443000        SEASON = 1.
00444000  C SUBSOLAR POINT (IN DEGREES; SOUTHERN HEMISPHERE IS NEGATIVE)
00445000        SSP = -23.433
00446000  C RADIUS VECTOR (DIMENSIONLESS)
00447000        V = 0.98372
00448000  C VALUES FOR SPRING AND SUMMER
00449000    2   IF (SEASON .EQ. 2.) SSP = 0.083
00450000        IF (SEASON .EQ. 2.) V = 0.99619
00451000        IF (SEASON .EQ. 3.) SSP = 23.450
00452000        IF (SEASON .EQ. 3.) V = 1.01630
00453000  C CONVERT SUBSOLAR POINT TO RADIANS
00454000        SSP = SSP * RAD
00455000  C BEGINNING OF 24 HOUR LOOP
00456000  C CALCULATION OF HOUR ANGLE
00457000        IHOUR = 0
00458000        HOUR = 180.
00459000        FLIP = -1.
00460000    4   IF (HOUR .EQ. 0.0) FLIP = 1.
```

```
00461000          HOUR = HOUR + (FLIP * 15.)
00462000          IHOUR = IHOUR + 1
00463000      C CONVERT HOUR ANGLE TO RADIANS
00464000          H = HOUR * RAD
00465000      C CALCULATE ZENITH ANGLE (EQUATION 7)
00466000          COSZ = SIN(LAT) * SIN(SSP) + COS(LAT) * COS(SSP) * COS(H)
00467000          Z = ARCOS(COSZ)
00468000      C CALCULATE SOLAR RADIATION ON TOP OF ATMOSPHERE ON HORIZONTAL SURFACE
00469000          QS = S / (V**2) * COSZ
00470000      C CALCULATE ARC COSINE OF SOLAR AZIMUTH (EQUATION 9)
00471000          COSAZ = (SIN(LAT) * COSZ - SIN(SSP)) / (COS(LAT) * SIN(Z))
00472000      C CHECK FOR ROUNDING ERROR
00473000          IF (COSAZ .GT. 1.) COSAZ = 1.
00474000          IF (COSAZ .LT. -1.) COSAZ = -1.
00475000      C CALCULATE SOLAR AZIMUTHS
00476000          SOLAZI = ARCOS(COSAZ)
00477000      C FROM 1 TO 11 A.M. DEDUCT AS FROM 360 DEGREES (AT NOON SOLAZI = 0.0)
00478000          IF (IHOUR .LT. 12) SOLAZI = 2 * PI - SOLAZI
00479000      C CONVERT SOLAR AZIMUTH TO DEGREES
00480000          SOLAZI = SOLAZI / RAD
00481000      C CONVERT ZENITH ANGLE TO DEGREES
00482000          Z = Z / RAD
00483000      C CHECK TO SEE IF NIGHT; IF IT IS, SKIP CALCULATIONS
00484000          IF (Z .GE. 90.0 .OR. Z .LE. 0.0) GO TO 140
00485000      C CALCULATE OPTICAL AIR MASS AT SEA LEVEL
00486000          MO = 1. / (COSZ + 0.15 * ((90. - Z) + 3.885) **(-1.253))
00487000      C CALCULATE BAROMETRIC PRESSURE AT ELEVATION
00488000          PZ = (1.0 - 0.0285 * ELEV) * 1013.
00489000      C CALCULATE OPTICAL AIR MASS AT ELEVATION
00490000          MZ = MO * (PZ / 1013.)
00491000      C CALCULATE PRECIPITABLE WATER VAPOR
00492000          W = 10. * 10.**(0.247 * SQRT(EA) - 0.579)
00493000      C CALCULATE THE TRANSMISSIVITY OF THE ATMOSPHERE - BROOK'S EQUATION
00494000          TZ = (EXP(-0.089 * (PZ * MZ / 1013.)**0.75 -
00495000         &       0.174 * (W * MZ / 20.)**0.6 -
00496000         &       0.083 * (D * MZ)**0.9))**(1.0 / MZ)
00497000      C CALCULATE DIRECT BEAM SOLAR RADIATION ON CLOUDLESS DAY ON
00498000      C    HORIZONTAL SURFACE
00499000          QHOR = QS * (TZ**MZ) * (1.0 - (1.0 - C) * N)
00500000      C CALCULATE DIFFUSE SOLAR RADIATION FOR HORIZONTAL SURFACE
00501000          QH = (0.15 + 0.85 * N) * QHOR
00502000      C TOTAL SOLAR RADIATION ON HORIZONTAL SURFACE
00503000          QAQHOR = QHOR + QH
00504000      C CHECK FOR NIGHT OR HIGH LATITUDE
00505000          IF (QAQHOR .LT. 0.0) QAQHOR = 0.0
00506000      C OUTPUT - SIMPLIFIED FOR CLARITY
00507000       140  CONTINUE
00508000       150  IF (IHOUR .GT. 1) GO TO 22
00509000            IF (SEASON .EQ. 1.) WRITE (8,200) LATDEG
00510000       200  FORMAT ('1                WINTER SOLSTICE       LATITUDE=',F5.0)
00511000            IF (SEASON .EQ. 2.) WRITE (8,201) LATDEG
00512000       201  FORMAT ('1                SPRING EQUINOX        LATITUDE=',F5.0)
00513000            IF (SEASON .EQ. 3.) WRITE (8,202) LATDEG
00514000       202  FORMAT ('1                SUMMER SOLSTICE       LATITUDE=',F5.0)
00515000            WRITE (8,210)
00516000       210  FORMAT (///, T20, 'HOUR', T30, 'SOLAR RADIATION RECEIVED ON ')
00517000       22   WRITE (8,220) IHOUR, QAQHOR
00518000       220  FORMAT (/, T20, I2, T30, F5.2)
00519000      C REINITIALIZE
00520000          QAQHOR = 0.0
00521000      C RETURN TO TOP OF DAY LOOP
00522000          IF (IHOUR .LT. 24) GO TO 4
00523000      C NEW SEASON
00524000          SEASON = SEASON + 1.
00525000          IF (SEASON .LE. 3.) GO TO 2
00526000          STOP
00527000          END
```

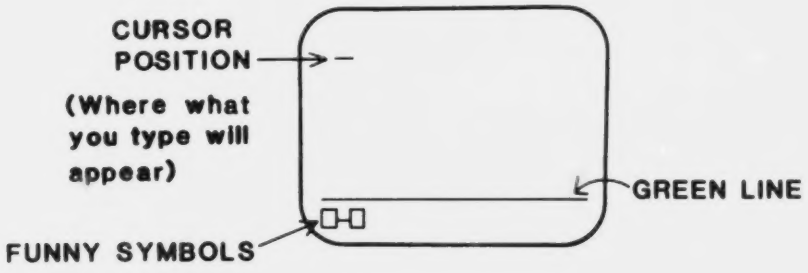
Directions for doing the exercise

These are exact instructions assuming no prior knowledge of using a computer terminal. Read the instructions carefully before attempting to use the computer.

Step 1: Sit yourself down in front of an IBM 3278 terminal. These are the "T.V. screen" terminals consisting of a typewriter-like keyboard and a screen. The largest number of them are found in the Graduate School of Management (2035 GSM).

The only keys that you need concern yourself with are the regular typewriter letter and number keys, the space bar (same as on a typewriter) and the ENTER key located in the lower right portion of the keyboard. Do not worry about upper and lower case letters.

When you see the screen, it will look like this:



Step 2: Type the following: logon (your account #). For example, if your account # is icpijkf, you would type logon icpijkf. Be sure to leave one space between the word logon and your account number.

Step 3: Hit the ENTER key. The next prompt will be for your password.

Step 4: Type in your password (for security reasons, your password will not appear on the screen).

Step 5: Hit ENTER key.

If you have not correctly typed the password, a message "Password not matched" will appear on the screen. Wait a few seconds and the prompt for your password will be repeated: try again and type it carefully, and hit ENTER again.

Then the screen will show that your logon is in progress, and the prompt READY will appear.

Step 6: Type the following: ex 'icpiobe.geog1.clist'. Remember to include the single quote marks when you type this, and leave one space between ex and '.

Step 7: Hit ENTER key. If you have typed Step 6 incorrectly, the response will indicate that the data set is not on catalogue (i.e., does not exist). In that case, simply type the information from Step 6 again as soon as the prompt READY reappears and hit ENTER again. This sequence can be repeated indefinitely if you keep making a mistake.

Step 8: What then follows is a series of explicit directions which will appear on the screen. The first one is:

TYPE YOUR LAST NAME. Type your last name and hit ENTER key. Continue answering the questions and hitting the ENTER key after every response you make. The last question asks for the latitude you were assigned. Type in your latitude and remember to include the decimal point, and then hit ENTER. A message will then appear indicating that you can pick up your output from your T.A. in a couple of days. Then hit ENTER once more and you are finished and off the computer.

Congratulations! You have just successfully completed this part of the exercise.

Other possible pitfalls:

1. If by mistake you hit ENTER at the beginning of the session before typing your account #, you will see a message saying the command is unrecognized. Don't worry about this. Just type in your account #, hit ENTER, and all will be well.

2. If at any time after you have started the computer session you feel confused or keep making a mistake which you can't figure out, you can end the session by typing in the word logoff.

Exercise

1. From the computer output generated for your assigned latitude, plot three curves (winter solstice, spring equinox, and summer solstice) for values of insolation.

   X axis -- hours of the day (1-24)
   Y axis -- solar radiation (langleys/min)

   Label each curve and the axes.

2. Indicate the hours of sunrise and sunset for each date (give the range, i.e., sunrise: 6-7:00 a.m.).

	Sunrise	Sunset
Winter solstice	_____	_____
Spring equinox	_____	_____
Summer solstice	_____	_____

3. Indicate the shortest day length and the date when this occurs.

   Day length: _____ Date: _____

4. What is the difference between the maximum values of insolation on the summer solstice and the winter solstice? _____

5. If your assigned latitude had been 10^{o} closer to the Equator, would the difference between maximum values (winter and summer solstices) have been greater or smaller? Why? _____

6. Calculate the noon solar altitude for your latitude for the solstices and spring equinox. Show your work in the space below.

   Winter solstice _____

   Spring equinox _____

   Summer solstice _____

7. If the albedo of the surface at your latitude is .3, how much solar radiation will be absorbed at the surface at noon on the spring equinox? Show work.

Sample output

NAME: HAYES , JOHN T.
SECTION: MONDAY 12
TA: ORLO ELFES

COMPUTER SIMULATION OF SOLAR RADIATION ASSIGNMENT

GEOGRAPHY 1
WINTER 1982
PROFESSOR WEIRICH

WINTER SOLSTICE LATITUDE= 34.

HOUR	SOLAR RADIATION RECEIVED ON HORIZONTAL SURFACE.
1	0.0
2	0.0
3	0.0
4	0.0
5	0.0
6	0.0
7	0.0
8	0.08
9	0.29
10	0.49
11	0.63
12	0.68
13	0.63
14	0.49
15	0.29
16	0.08
17	0.0
18	0.0
19	0.0
20	0.0
21	0.0
22	0.0
23	0.0
24	0.0

SPRING EQUINOX LATITUDE= 34.

HOUR	SOLAR RADIATION RECEIVED ON HORIZONTAL SURFACE.
1	0.0
2	0.0
3	0.0
4	0.0
5	0.0
6	0.00
7	0.15
8	0.45
9	0.75
10	1.00
11	1.16
12	1.21
13	1.16
14	1.00
15	0.75
16	0.45
17	0.15
18	0.00
19	0.0
20	0.0
21	0.0
22	0.0
23	0.0
24	0.0

SUMMER SOLSTICE LATITUDE= 34.

HOUR	SOLAR RADIATION RECEIVED ON HORIZONTAL SURFACE.
1	0.0
2	0.0
3	0.0
4	0.0
5	0.00
6	0.15
7	0.44
8	0.75
9	1.04
10	1.27
11	1.41
12	1.46
13	1.41
14	1.27
15	1.04
16	0.75
17	0.44
18	0.15
19	0.00
20	0.0
21	0.0
22	0.0
23	0.0
24	0.0

In calories per square centimeter per minute

5. ATMOSPHERIC MOISTURE

For most students, an understanding of atmospheric moisture processes is contingent upon a thorough grasp of basic phase relationships and a clear understanding of the distinction between terms such as specific and relative humidity or the different lapse rates. Once this is achieved, it then becomes possible to undertake some basic calculating and graphing effort to demonstrate the types of changes produced in atmospheric parcels as they undergo altitude, temperature, and moisture content changes.

In addition to the usual list of terms, a brief discussion of some of the key concepts has been included. Experience has shown that once this material is understood most students have little difficulty completing the exercises. Of the three exercises which have been included in this section, the first is relatively easy while most students find the last two of somewhat greater difficulty.

Concepts to cover:

Phase changes

Latent heat

Sensible heat

Humidity

Relative humidity

Specific humidity

Lapse rates (wet, dry, and environmental)

A more detailed discussion of specific concepts

Water exists on earth in all three phases: liquid, solid, gas

The phase change of water to a less ordered state requires an input of energy (er. absorbed from the environment), e.g. sweat cools our bodies by evaporation--p. change of liquid to vapor--removes 600 calories of heat from our body for every gram . water evaporated.

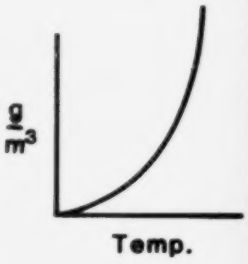
The phase change of water to a more ordered state releases energy to surrounding environment.

Water vapor in the atmosphere represents locked-up energy. This is known as LATENT HEAT. The force of hurricanes is sustained by energy released through condensation--conversion of latent heat to sensible.

Humidity--water vapor in the atmosphere.

Specific humidity-- grams H_2O/M^3 air (mass/volume) or grams H_2O/kg air (mass/mass)

Relative humidity-- $$\frac{\text{grams of } H_2O \text{ in } m^3 \text{ of air}}{\text{maximum grams of } H_2O \text{ that } m^3 \text{ air could hold}}$$

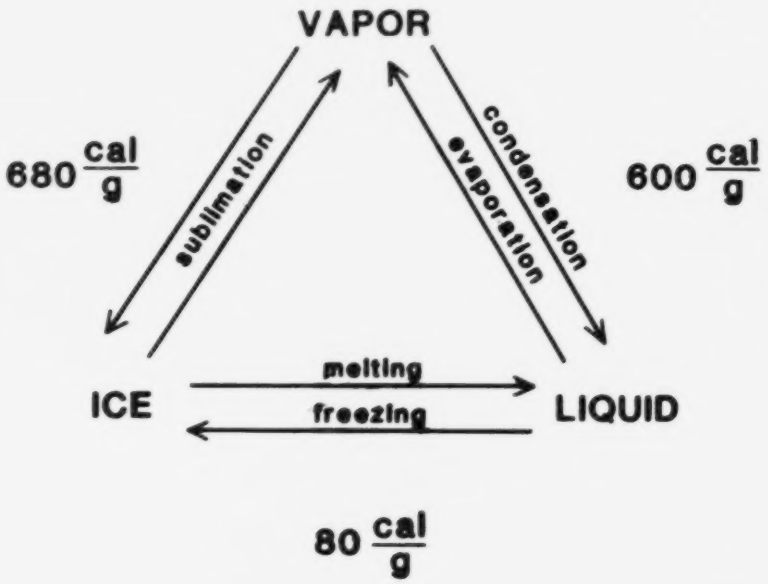


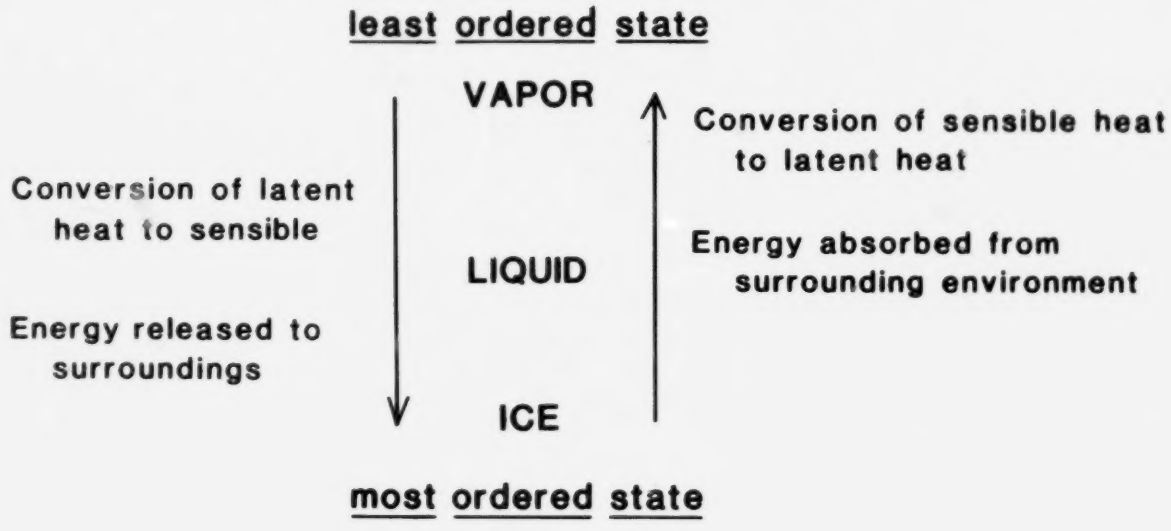
Written another way: $$\frac{\text{specific humidity}}{\text{maximum specific humidity}}$$

This relation shows that for a given specific humidity, a change in air temperature will inversely change the relative humidity, i.e.:

↑ T ➡ ↓ RH

↓ T ➡ ↑ RH





Mr. Wizard Time: Psychrometer demonstration
- o As water evaporates from wet bulb sensible heat is removed; that's why.
- o How to use psychrometric tables.

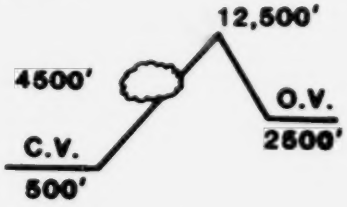
ADIABATIC LAPSE RATES

As a parcel of air rises, it cools due to decreasing air pressure
- o This↓ T results in↑ RH.

Dry adiabatic lapse rate (DALR)-5.5°F/1000'

Wet adiabatic lapse rate (WALR)-3.2°F/1000'
- o Condensation slows the rate of cooling in a saturated parcel.

Compressional heating--descending air warms at DALR.



Observations from example:

1. Although air moving from Central Valley to Owens Valley experienced an overall elevation gain, the overall temperature change was + 7.4°F.
2. Hotter air (for given specific humidity) ⟹ drier air.
3. Prevailing W to E air movement has produced rain shadow in Owens Valley.

4. Orographic precipitation on west slope of Sierra.

5. Same process responsible for Mojave Desert and aridity of western United States.

EXAMPLE: AIR MASS MOVING OVER SIERRA

Conventions & constants:

ΔT = change in temperature of air mass, $\pm$ °F

rate = appropriate adiabatic rate: DALR = -5.5°F/1000'
WALR = -3.2°F/1000'

Δ alt = change in elevation, $\pm$ feet

Guiding equation: $\Delta T = \text{rate} \times \Delta \text{alt}$

1. Initial conditions: An air mass in California's Central Valley (elevation = 500') is at 85°F, RH < 100%. We are told that the condensation level will be 4500'. Owens Valley elevation = 2500'.

2. From 500' to 4500'

$\Delta T = -5.5°F/1000' \times 4000' = -22°F$

$T_{4500} = T_{500} + \Delta T = 85°F - 22°F = 63°F$ (= Tdew)

3. From 4500' to 12,500'

$\Delta T = -3.2°F/1000' \times 8000' = -25.6°F$

$T_{12500} = T_{4500} + \Delta T = 63°F - 25.6°F = 37.4°F$

4. From 12,500' to 2500' (Owens Valley)

$\Delta T = -5.5°F/1000' \times -10,000' = +55°F$

$T_{2500} = T_{12500} + \Delta T = 37.4°F + 55°F = 92.4°F$

Version A

1. Use the attached psychrometric tables to determine the relative humidity and dew point temperature for the following observations.

   (a) Dry bulb 70°F RH_____%
   Wet bulb 60°F Dew point_____°F

   (b) Dry bulb 100°F RH_____%
   Wet bulb 70°F Dew point_____°F

   (c) Dry bulb 30°F RH_____%
   Wet bulb 22°F Dew point_____°F

2. From (a) and (b) above, the greater the difference between dry bulb and wet bulb readings the _____ (higher or lower) the relative humidity.

3. On a humid day, will there be a large or small difference between wet and dry bulb readings compared to a dry day?

4. Given: dry adiabatic lapse rate -5.5°F/1000'
   wet adiabatic lapse rate -3.2°F/1000'

   A 90°F parcel of air at sea level is forced over a 7000' mountain range and then descends to a 1000' valley. Dew point temperature is reached at 2000'. Showing your work, give:

   (a) Dew point temperature
   (b) Temperature at 7000'
   (c) Temperature at 1000' (in the valley)

5. One side of Hawaii is drier than the other. Given that Hawaii is mountainous and lies in the Trade Winds, explain this fact.

PSYCHROMETRIC TABLES

TABLE A

Dew-Point Temperature (°F) and Saturation Vapor Pressure (in. Hg)
(Pressure = 30 in. Hg)

Air Temperature (°F)	Vapor Pressure (in. Hg)	Depression of Wet-bulb Thermometer (°F)														
		1	2	3	4	5	6	7	8	9	10	15	20	25	30	35
20	0.110	16	12	8	2	− 7	−21									
25	0.135	22	19	15	10	5	− 3	−15	−51							
30	0.166	27	25	21	18	14	8	2	− 7	−25						
35	0.203	33	30	28	25	21	17	13	7	0	−11					
40	0.248	38	35	33	30	28	25	21	18	13	7					
45	0.300	43	41	38	36	34	31	28	25	22	18					
50	0.362	48	46	44	42	40	37	34	32	29	25	− 2				
55	0.436	53	51	50	48	45	43	41	38	36	33	14				
60	0.522	58	57	55	53	51	49	47	45	43	40	25	−11			
65	0.622	63	62	60	58	57	55	53	51	49	47	34	14			
70	0.739	69	67	65	64	62	61	59	57	55	53	42	26	−14		
75	0.875	74	72	71	69	68	66	64	63	61	59	49	36	15		
80	1.032	79	77	76	74	73	72	70	68	67	65	56	44	28	− 7	
85	1.214	84	82	81	80	78	77	75	74	72	71	62	52	39	19	
90	1.422	89	87	86	85	83	82	81	79	78	76	69	59	48	32	1
95	1.661	94	93	91	90	89	87	86	85	83	82	74	66	56	43	24
100	1.933	99	98	96	95	94	93	91	90	89	87	80	72	63	52	37
105	2.244	104	103	101	100	99	98	96	95	94	93	86	78	70	61	48
110	2.597	109	108	106	105	104	103	102	100	99	98	91	84	77	68	57
115	2.996	114	113	112	110	109	108	107	106	104	103	97	90	83	75	66

TABLE B

Relative Humidity (Percent)
(Pressure = 30 in. Hg)

Air Temperature (°F)	Depression of Wet-bulb Thermometer (°F)														
	1	2	3	4	5	6	7	8	9	10	15	20	25	30	35
20	85	70	55	40	26	12									
25	87	74	62	49	37	25	13	1							
30	89	78	67	56	46	36	26	16	6						
35	91	81	72	63	54	45	36	29	19	10					
40	92	83	75	68	60	52	45	37	29	22					
45	93	86	78	71	64	57	51	44	38	31					
50	93	87	80	74	67	61	55	49	43	38	10				
55	94	88	82	76	70	65	59	54	49	43	19				
60	94	89	84	78	73	68	63	58	53	48	26	5			
65	95	90	85	80	75	70	66	61	56	52	31	12			
70	95	90	86	81	77	72	68	64	59	55	36	19	3		
75	96	91	86	82	78	74	70	66	62	58	40	24	9		
80	96	91	87	83	79	75	72	68	64	61	44	29	15	3	
85	96	92	88	84	80	76	73	69	66	62	46	32	20	8	
90	96	92	89	85	81	78	74	71	68	65	49	36	24	13	3
95	96	93	89	85	82	79	75	72	69	66	51	38	27	17	7
100	96	93	89	86	83	80	77	73	70	68	54	41	30	21	12
105	97	93	90	87	83	80	77	74	71	69	55	43	33	23	15
110	97	93	90	87	84	81	78	75	73	70	57	46	36	26	18
115	97	94	91	88	85	82	79	76	74	71	58	47	37	28	21

Source: Elements of Meteorology by Miller

Version B

1. Use the attached psychrometric tables to determine the relative humidity and dew point temperature for the following observations.

   (a) Dry bulb 70°F RH_____%
   Wet bulb 60°F Dew point_____°F

   (b) Dry bulb 100°F RH_____%
   Wet bulb 70°F Dew point_____°F

   (c) Dry bulb 30°F RH_____%
   Wet bulb 22°F Dew point_____°F

2. From (a) and (b) above, the greater the difference between dry bulb and wet bulb readings the _____ (higher or lower) the relative humidity. Why?

3. During your morning run you sweat 20 grams of water which evaporates. How many calories have been removed from your skin through evaporation? _____
   This phase demonstrates (circle one):
   (a) the conversion of sensible heat to latent heat
   (b) the conversion of latent heat to sensible heat.

4. How much energy would be required to melt a 3 kilogram block of ice?_____ calories.

5. Will the difference between wet bulb and dry bulb readings be large or small on a very dry day (e.g., RH = 15%)? _____

6. Given: dry adiabatic lapse rate is -5.5°F/1000'
   wet adiabatic lapse rate is -3.2°F/1000'

   A 90°F parcel of air is forced to rise over a 7000' mountain range and then descends to a 1000' valley. Dew point is reached at 2000'. Showing your work, give:
   (a) Dew point temperature
   (b) Temperature at 7000'
   (c) Temperature at 1000' (in the valley).

7. One side of Hawaii is drier than the other. Given that Hawaii is mountainous and lies in the Trade Winds, explain this fact.

PSYCHROMETRIC TABLES

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Dew-Point Temperature (°F) and Saturation Vapor Pressure (in. Hg)
(Pressure = 30 in. Hg)

Air Temperature (°F)	Vapor Pressure (in. Hg)	Depression of Wet-bulb Thermometer (°F)														
		1	2	3	4	5	6	7	8	9	10	15	20	25	30	35
20	0.110	16	12	8	2	− 7	−21									
25	0.135	22	19	15	10	5	− 3	−15	−51							
30	0.166	27	25	21	18	14	8	2	− 7	−25						
35	0.203	33	30	28	25	21	17	13	7	0	−11					
40	0.248	38	35	33	30	28	25	21	18	13	7					
45	0.300	43	41	38	36	34	31	28	25	22	18					
50	0.362	48	46	44	42	40	37	34	32	29	25	− 2				
55	0.436	53	51	50	48	45	43	41	38	36	33	14				
60	0.522	58	57	55	53	51	49	47	45	43	40	25	−11			
65	0.622	63	62	60	59	57	55	53	51	49	47	34	14			
70	0.739	69	67	65	64	62	61	59	57	55	53	42	26	−14		
75	0.875	74	72	71	69	68	66	64	63	61	59	49	36	15		
80	1.032	79	77	76	74	73	72	70	68	67	65	56	44	28	− 7	
85	1.214	84	82	81	80	78	77	75	74	72	71	62	52	39	19	
90	1.422	89	87	86	85	83	82	81	79	78	76	69	59	48	32	1
95	1.661	94	93	91	90	89	87	86	85	83	82	74	66	56	43	24
100	1.933	99	98	96	95	94	93	91	90	89	87	80	72	63	52	37
105	2.244	104	103	101	100	99	98	96	95	94	93	86	78	70	61	48
110	2.597	109	108	106	105	104	103	102	100	99	98	91	84	77	68	57
115	2.996	114	113	112	110	109	108	107	106	104	103	97	90	83	75	66

TABLE B

Relative Humidity (Percent)
(Pressure = 30 in. Hg)

Air Temperature (°F)	Depression of Wet-bulb Thermometer (°F)														
	1	2	3	4	5	6	7	8	9	10	15	20	25	30	35
20	85	70	55	40	26	12									
25	87	74	62	49	37	25	13	1							
30	89	78	67	56	46	36	26	16	6						
35	91	81	72	63	54	45	36	29	19	10					
40	92	83	75	68	60	52	45	37	29	22					
45	93	86	78	71	64	57	51	44	38	31					
50	93	87	80	74	67	61	55	49	43	38	10				
55	94	88	82	76	70	65	59	54	49	43	19				
60	94	89	84	78	73	68	63	58	53	48	26	5			
65	95	90	85	80	75	70	66	61	56	52	31	12			
70	95	90	86	81	77	72	68	64	59	55	36	19	3		
75	96	91	86	82	78	74	70	66	62	58	40	24	9		
80	96	91	87	83	79	75	72	68	64	61	44	29	15	3	
85	96	92	88	84	80	76	73	69	66	62	46	32	20	8	
90	96	92	89	85	81	78	74	71	68	65	49	36	24	13	3
95	96	93	89	85	82	79	75	72	69	66	51	38	27	17	7
100	96	93	89	86	83	80	77	73	70	68	54	41	30	21	12
105	97	93	90	87	83	80	77	74	71	69	55	43	33	23	15
110	97	93	90	87	84	81	78	75	73	70	57	46	36	26	18
115	97	94	91	88	85	82	79	76	74	71	58	47	37	28	21

 Source: Elements of Meteorology by Miller

Version C

Materials: Graph paper (five squares to the centimeter), straight edge, red pencil, ball-point pen (any color).

Instructions:

1. Draw a horizontal and a vertical line in such a manner as to divide the graph paper into four equal quadrants (sections).

2. Orienting the graph paper in a horizontal manner, label the quadrants A, B, C, and D. Place your name in the upper right hand corner.

3. In each quadrant lay out a horizontal scale for temperature, in degrees Celsius, from -25 at the left to +25 at the right. Let five spaces represent five degrees.

4. In each quadrant lay out a vertical scale for elevation in meters, from sea level (0m) up to 3000 meters. Let five spaces represent 500 meters.

5. In ink, draw a solid line from +25C at sea level upward to 3000 meters with a temperature decrease of 10C/1000m. Label this line DAR (dry adiabatic rate).

6. In ink, draw a broken (dashed or dotted) line from +25C at sea level upward to 3000 meters with a temperature decrease of 6C/1000m. Label this line SAR (saturation adiabatic rate).

7. Make both of these lines described in #5 and #6 in each of the quadrants.

8. In red pencil, draw the following ELR (environmental lapse rate) lines in the quadrants as lettered and label accordingly; i.e., stable, unstable, conditional instability.

Quadrant A: ELEVATION	TEMP.
0m	25C
500m	19
1000m	13
1500m	7
2000m	1
2500m	-5
3000m	-11

Quadrant B: ELEVATION	TEMP.
0m	25C
500m	23
1000m	21
1500m	19
2000m	17
2500m	15
3000m	13

Quadrant C: ELEVATION	TEMP.
0m	25C
500m	21
1000m	17
1500m	13
2000m	9
2500m	5
3000m	1

Quadrant D: ELEVATION	TEMP.
0m	25C
500m	22
1000m	19
1500m	28
2000m	24
2500m	20
3000m	15

6. WEATHER MAPS

The deciphering of weather maps for some students is a tedious exercise in interpreting symbols, while for others it becomes an exciting experience in interpreting and understanding how the movement of air masses is documented and predictions of weather carried out. The success or failure of weather map exercises often centers upon the success or failure of the instructor to convey the real world significance of the often complex hieroglyphics presented on the map. If students realize how important slight variations in symbolization may be, then they seem to have little difficulty involving themselves in interpreting the weather maps.

While the same basic map data must be absorbed for most exercises, there is considerable variation in how the actual exercise may be carried out. This variability is reflected in the range of exercises which follows. The first allows for the use of local map data; the second provides a broader regional view of the processes underway; while the third attempts a national scale picture of processes underway. Although not included in this collection, several exercises using weather service data are also available in many of the lab manuals. Usually, a symbol interpretation scheme is included and this should allow for the adaptation of such exercises as complete units into a course structure if it is felt that more weather map experience is desirable.

Topics to cover

Barometric pressure

Pressure gradients

Basic units (millibar, etc.)

Basic map symbolization

Version A

Obtain weather maps for two consecutive days from a newspaper. Make sure they include: (1) warm, cold, and occluded fronts; (2) location of precipitation; and (3) temperatures (likely to found in an adjacent table).

For the first map:

1. Give the lowest pressure and location of each cyclone. _____
2. Explain light and heavy rain or snow occuring in the vicinity of a frontal system. _____

For both maps:

Find a city which is in front of a cold front on the first day and behind it on the second. What has happened to the temperature and precipitation? Explain your findings. What wind directions would you expect for each day at that city? Why?

Questions related to detailed weather maps

For one map:

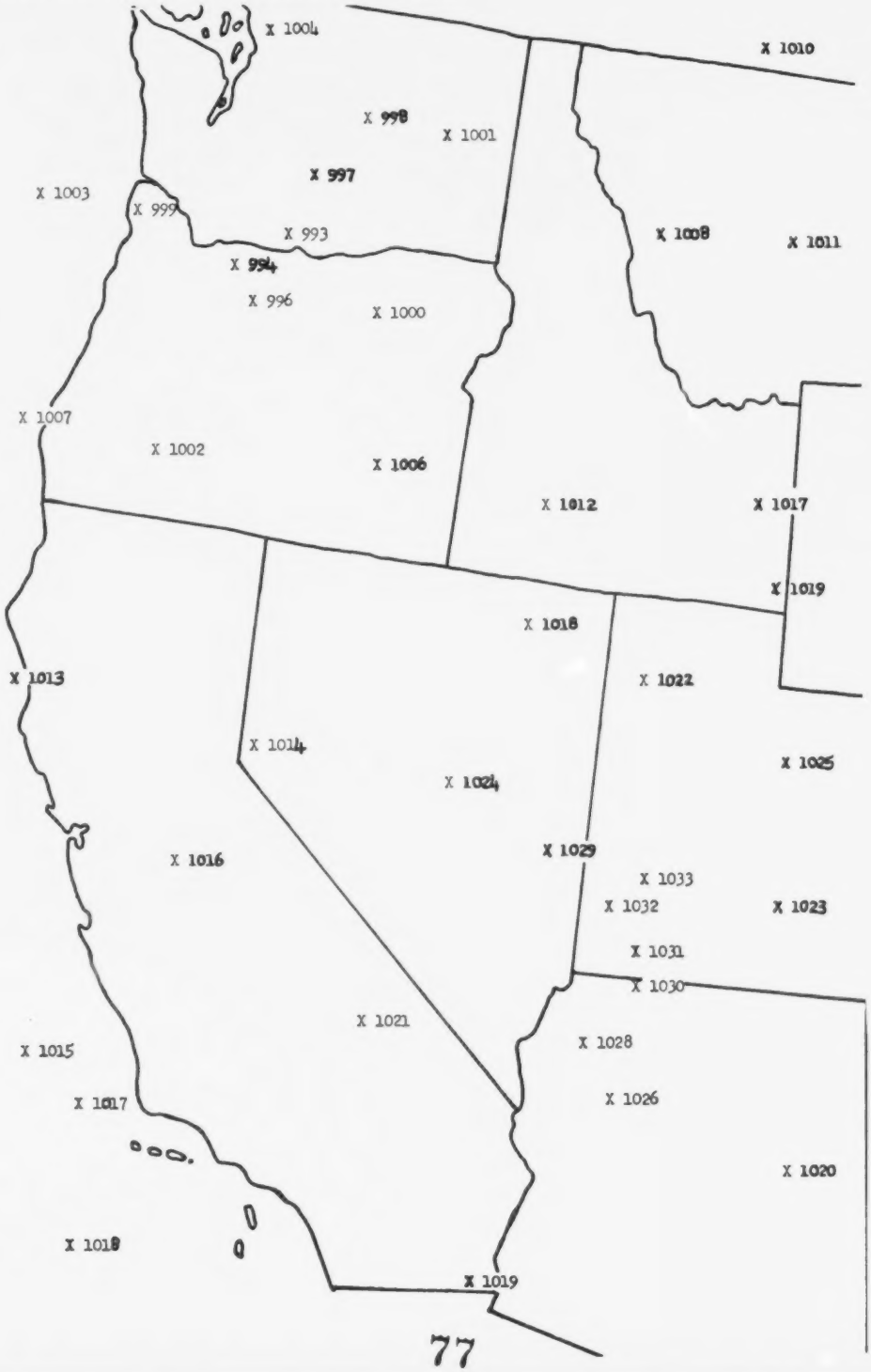
1. Where are the cyclones and anticyclones? _____
2. For a cyclone, are the winds diverging or converging? Flowing clockwise or counterclockwise? _____
3. Based only on your answer to #2, in what hemisphere is the area shown? _____

For consecutive maps:

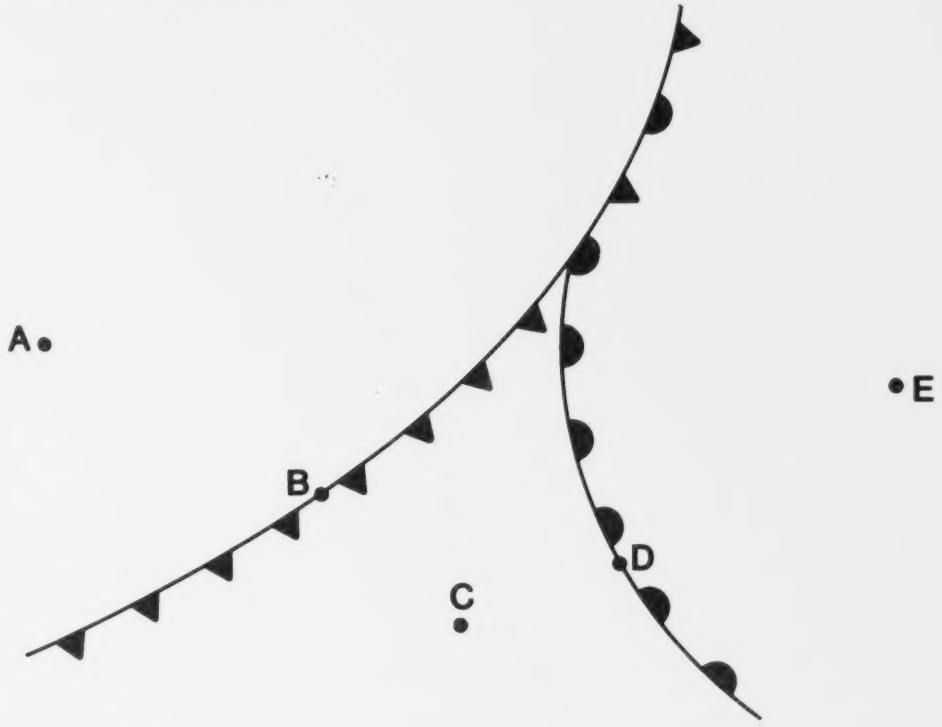
1. How fast is a particular cyclone moving? _____
2. Where do you expect the cyclone to be in twenty-four hours? _____
3. For a city which was ahead of a cold front on the first map and behind it on the second, what has happened to: (a) temperature; (b) precipitation; (c) wind speed and direction; and (d) air pressure? Do these findings correspond to what your text says about the passing of a cold front? If not, what may have caused the discrepancy? _____

Version B

On the following map, the numerals marked at "X" represent barometric pressure in millibars. Draw and number isobars at four (4) millibar intervals commencing with 1012mb; label the resulting high and low pressure centers and draw arrows to indicate the approximate wind directions crossing the isobars. The final product must be in ink, although it is strongly recommended that preliminary work be conducted in pencil until satisfied that the isobars are accurately drawn.



Describe the general weather conditions associated with points A, B, C, D, and E in the figure below. Assume it is winter.



1. Sky conditions (cloudy, clear)
2. Wind conditions (direction, velocity)
3. Pressure conditions (relative)
4. Temperature (relative)
5. Precipitation (assume rain; intensity)

Version C

Directions: Plot the following weather report information at the appropriate locations on a blank map of the United States. Then draw in the isobars at intervals of 4 mb, i.e., 1004, 1008, etc. Remember to follow the format used by the U.S. Weather Service as shown in the textbook. Also, do not forget to locate and draw in the fronts which may be part of the information. After completing the map, turn it over and write a description of the weather pattern over the United States for the map you have drawn.

LOCATION	WIND DIRECTION AND SPEED (kts)	PRESSURE (mb)	TEMPERATURE (°F)
Los Angeles, CA	S - 5	1022	61
San Francisco, CA	NW - 5	1025	57
Seattle, WA	SW - 5	1029	52
Boise, Idaho	W - 10	1023	55
Helena, Montana	SW - 15	1015	57
Casper, Wyoming	SW - 15	1013	48
Salt Lake City	SE - 10	1023	52
Denver, Colorado	S - 5	1015	45
Phoenix, Arizona	E - 5	1018	61
Las Vegas, NV	E - 10	1022	59
Albuquerque, NM	NW - 10	1018	57
Bismarck, ND	WSW - 5	1003	46
Omaha, Nebraska	SW - 5	1012	43
Dodge City, Kansas	S - 10	1016	43
Oklahoma City	NNW - 5	1016	52
San Antonio, TX	SE - 5	1013	79
Fort Worth, Texas	NE - 10	1014	64
Little Rock, AR	WSW - 10	1011	63
New Orleans, LA	SSW - 5	1014	73
Kansas City, MO	W - 5	1014	48
Minneapolis, MN	SW - 10	1008	43
Des Moines, Iowa	W - 5	1012	39
Chicago, Illinois	NE - 10	1007	45
Indianapolis, IN	NE - 10	999	48
Columbus, Ohio	E - 10	1003	46
Louisville, KY	NE - 5	997	57
Nashville, TN	SW - 20	999	68
Birmingham, AB	SW - 15	1008	70
Atlanta, Georgia	S - 10	1010	66
Charlotte, NC	SSW - 15	1008	66
Pittsburgh, PA	NE - 10	1008	46
Roanoke, VA	SE - 10	1008	50
Philadelphia, PA	ESE - 5	1016	45
Detroit, MI	NE - 10	1007	45
Buffalo, NY	ESE - 5	1013	43
Miami, Florida	ESE - 5	1017	75
Portland, Maine	0 - 0	1018	32
Springfield, MO	NW - 15	1013	46
Jackson, MS	SW - 10	1010	73

CLIMATIC CLASSIFICATION

7. CLASSIFYING GLOBAL CLIMATE PATTERNS

Climate classification brings together aspects of earth-sun relationships, energy balance climatology, atmospheric moisture, and weather. Central to the use of any of the classification schemes, however, is a clear understanding of the purpose behind and the operating assumptions underlying each scheme. What climatic and other factors have the highest priority in a scheme must be conveyed to the student if a clear understandig of the application of the differing methods of classification is to be effective. A thorough understanding of classification based interpretative tools such as climographs is also essential.

Four different climate classification exercises are described in the following pages. All seek to improve the student's ability to apply classifications or extract data from classification schemes. No list of terms is provided in this section. The terms needed will vary with the classification scheme used in the text selected for the course. The Köppen scheme is briefly discussed as an example of a scheme. Other schemes may be preferred.

Version A

The following is temperature (in °F) and precipitation (in inches) data for six stations around the world. Data are presented on a monthly basis.

		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1.	T	44.4	44.3	45.0	48.0	52.0	56.7	58.8	58.9	56.6	51.5	47.5	45.5
	P	5.5	5.2	4.5	3.7	3.1	3.2	3.8	4.8	4.1	5.6	5.5	6.5
						Annual Totals:		T 50.8 average					
								P 55.7					
2.	T	45.5	50.5	55.0	58.5	64.0	70.0	74.0	73.0	70.0	62.5	54.0	46.5
	P	3.8	2.8	2.8	1.5	0.8	0.1	-	-	0.3	0.8	1.9	3.8
						Annual Totals:		T 60.5 average					
								P 18.6					
3.	T	79.5	81.0	83.5	85.5	84.0	82.0	81.5	81.5	81.0	81.0	80.0	79.0
	P	0.6	0.1	0.5	1.7	8.7	13.0	12.4	10.6	13.2	10.6	4.5	2.2
						Annual Totals:		T 82.0 average					
								P 78.1					
4.	T	-24.9	-26.0	-13.7	2.5	21.0	36.7	47.8	47.3	37.0	21.7	0.0	-15.3
	P	0.3	0.3	0.4	0.7	0.5	1.0	1.8	1.6	1.5	1.2	0.8	0.6
						Annual Totals:		T 11.3 average					
								P 10.7					
5.	T	56.0	58.5	63.5	70.0	77.0	81.5	83.0	83.0	79.0	75.5	68.0	59.0
	P	0.2	0.2	0.2	0.1	0.1	-	-	-	-	-	0.1	0.2
						Annual Totals:		T 71.5 average					
								P 1.1					
6.	T	-14.8	-6.5	11.3	32.4	47.5	60.8	64.8	59.9	45.5	30.4	5.7	-10.0
	P	0.1	0.1	0.2	0.3	0.8	2.0	3.7	3.5	2.0	0.5	0.3	0.1
						Annual Totals:		T 27.1 average					
								P 13.6					

Questions

1. Determine the climate (Köppen system) for each of the stations listed. Use the attached key for making your determination.

   1.___ 2.___ 3.___ 4.___ 5.___ 6.___

2. Check a map of Köppen climates. Name a place or area that might have the monthly and annual figures presented for each station.

   1._____ 2._____ 3._____

   4._____ 5._____ 6._____

MODIFIED KEY TO THE KÖPPEN SYSTEM

First element

A - Tropical climate: average temperature every month above 64.4°F.

B - Dry climate: precipitation low; Ep greater than P every month of year; tend to high or moderate monthly temperatures.

C - Warm temperate (mesothermal) climate: average temperature of coldest month below 64.4°F but above 26.6°F; at least one month above 50°F.

D - Snow (microthermal) climate: coldest month average temperature below 26.6°F; warmest month above 50°F.

E - Ice climate: average temperature of warmest month below 50°F (no second or third element need be added to this).

Second element

f - moist; rainfall in all months

w - dry season in winter

s - dry season in summer

m - moist; high rainfall with short dry season

FOR B CLIMATES ONLY:

S - steppe: semi-arid with 15 to 30 inches of annual rainfall

W - desert: arid with usually less than ten inches of annual rainfall

Third element

a - hot summer, warmest month above 71.6°F

b - warm summer, warmest month below 71.6°F

c - cool, short summer with less than four months above 50°F

d - very cold winter with coldest month below -36.4°F

FOR B CLIMATES ONLY:

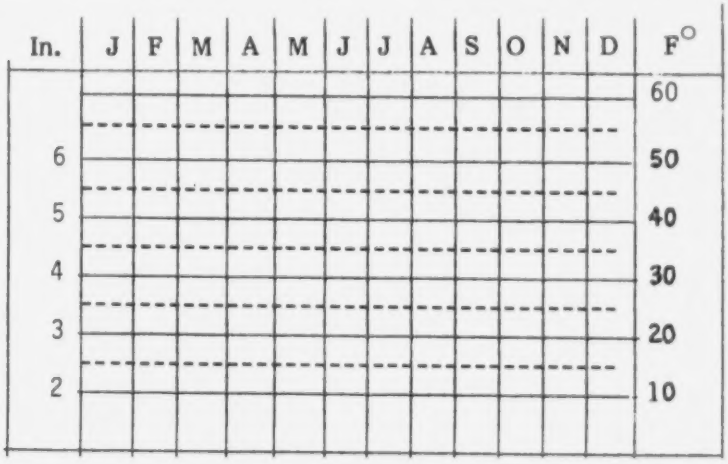
h - dry and hot with mean annual temperature above 64.4°F

k - dry and cold with mean annual temperature below 64.4°F

Version B

Given the following climatic data, plot the temperature and precipitation on the climograph.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
T	26	27	37	42	48	52	64	57	49	43	36	28	42
P	2.1	2.1	2.6	2.9	3.6	3.3	3.4	3.0	3.1	2.6	2.4	2.4	33.2



1. Using the Köppen system, what type of climate is this? (use letters) _____

2. Looking on a climate map, what is the name of this climate and the three others very similar to it? _____

3. Looking on a natural vegetation map, what natural vegetation region corresponds with this type of climate? _____

4. How do you know this particular station is in the northern hemisphere? _____
_____

5. Is there a similar climate and natural vegetation region in the southern hemisphere? _____

6. Why or why not, is there or isn't there, a similar climate in the southern hemisphere? _____

7. Looking at a soils map, is there a particular soils group that corresponds in general to this type of climate and natural vegetation region? _____ If there is, what is the name of it? _____

Version C

Below are temperature and rainfall data for a number of weather stations. Before answering any questions on this page, plot the climatic data on the graphs provided.

Station Data

		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
1.	°F	54.6	55.5	57.5	59.4	62.2	66.4	70.2	71.1	69.0	65.3	60.9	56.6	62.4
	In	3.1	3.1	2.8	1.0	0.4	0.1	T	T	0.2	0.7	1.2	2.6	15.2
2.	°F	19.0	21.0	32.0	48.0	64.0	73.0	77.0	74.0	63.0	50.0	37.0	26.0	49.0
	In	0.5	0.3	0.4	0.5	0.7	0.7	0.5	0.5	0.5	0.4	0.4	0.5	5.9
3.	°F	80.	80.	79.	77.	74.	71.	70.	70.	71.	74.	77.	79.	75.0
	In	14.4	14.8	17.8	15.7	10.4	11.1	11.9	8.0	5.2	3.9	4.6	10.3	128.2
4.	°F	39.	41.	50.	59.	68.	76.	79.	78.	72.	69.	49.	41.	59.
	In	4.8	4.2	5.1	4.4	3.8	4.2	4.1	3.5	3.5	2.4	3.5	3.9	47.4
5.	°F	72.5	75.2	81.	81.0	92.5	93.4	89.6	87.8	89.2	88.9	82.0	74.7	84.0
	In	0	0	0	0	0.1	0.3	1.8	2.6	0.7	0.2	0	0	5.7
6.	°F	-19.	-13.	-14.	-2.	21.	35.	40.	39.	31.	16.	1.	-15.	10.0
	In	0.3	0.2	0.2	0.3	0.3	0.3	1.1	0.8	0.5	0.8	0.4	0.4	5.6
7.	°F	80.5	82.	84.2	85.	83.6	80.0	79.0	79.2	79.9	80.4	81.1	80.7	81.3
	In	0.8	0.8	1.7	3.7	11.4	27.8	25.3	12.5	9.2	12.9	6.7	1.9	114.7
8.	°F	-23.1	-11.3	3.8	29.1	46.4	56.7	59.3	54.3	42.4	25.1	0.7	-13.1	22.5
	In	0.8	0.8	0.5	0.7	0.9	1.3	1.6	1.6	1.7	1.3	1.3	1.1	13.6

1. Which of the above stations (indicate by number) refers to Khartoum, Sudan, and has a tropical desert (BW) climate?_____ How can you identify it as a tropical desert climate (give two reasons). _____
_____

2. Astrakhan, Soviet Union (Station ___) receives only slightly more precipitation than Khartoum, Sudan, and has a BS climate. What is the major difference between these two arid climates? _____
_____

3. Which station has a tropical wet (Af) climate and refers to Tamatave, Malagasy Republic?_____ What two features make it an Af climate?
_____

4. A tropical wet-and-dry climate at Cochin, India (an Am climate) is indicated by the figures for station number ___.

5. The figures for the subtropical dry summer (Cs) or Mediterranean climate at Los Angeles are given as station number ___.

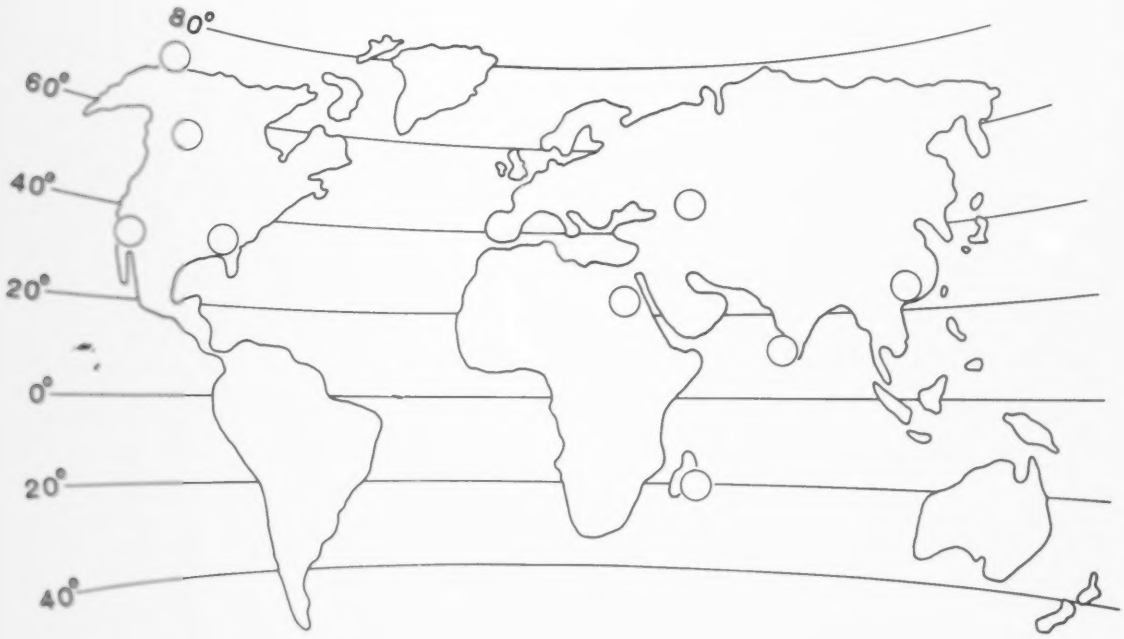
6. Which station exhibits a humid subtropical climate (Cfa) with adequate year-round rainfall? _____

7. One of the places, Dawson, Canada, has a boreal climate (Dfc). This station is number _____. How can you tell it is not an ET or tundra climate? _____

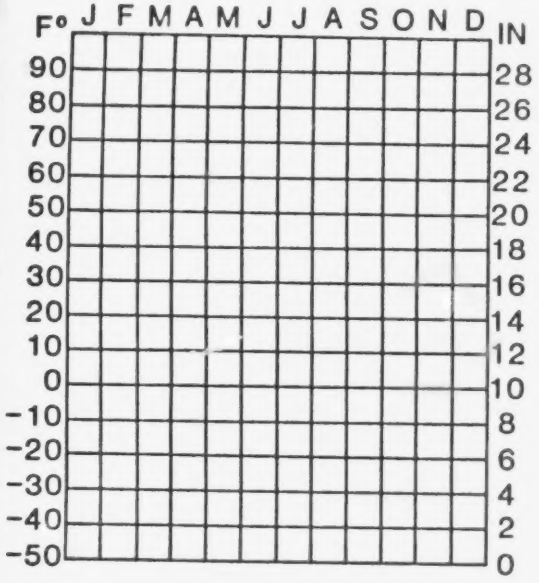
_____

8. Point Barrow, Alaska, has a tundra climate (ET). This is station number ___. During which season is precipitation greatest and why would you expect this?

_____



STATION _____



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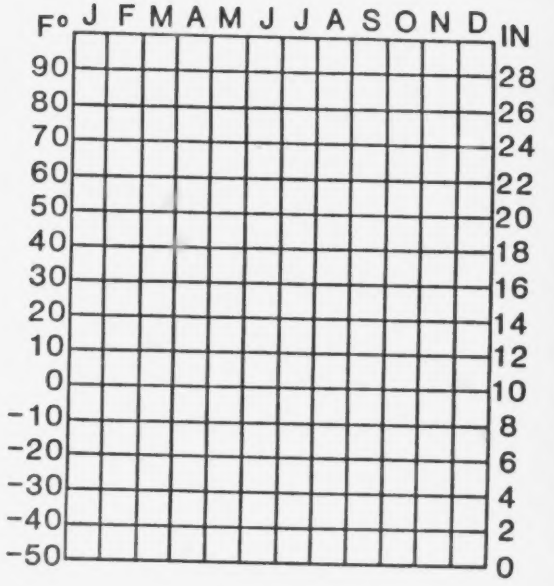

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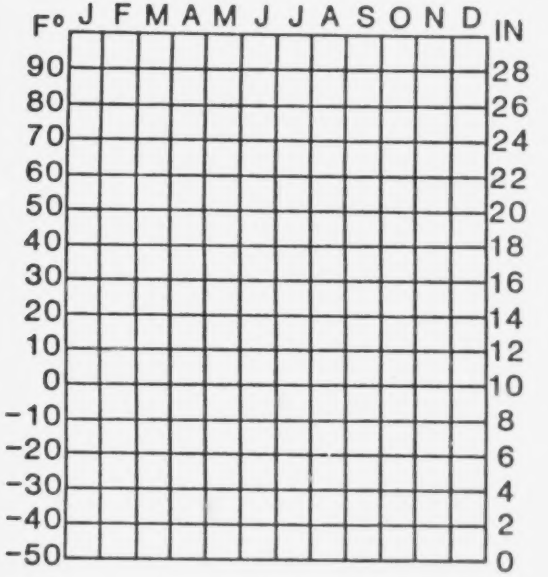

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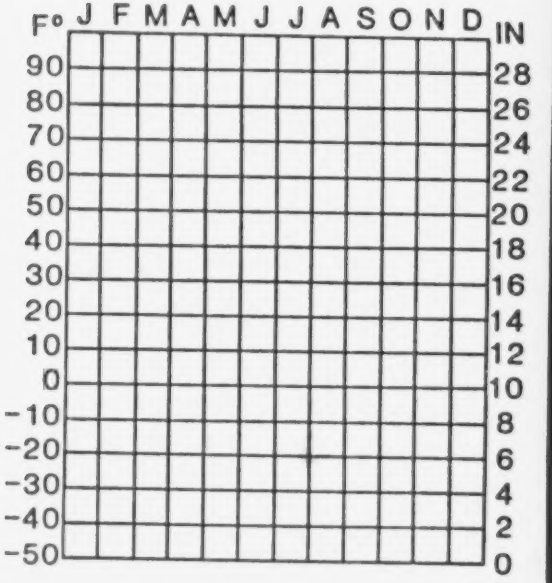

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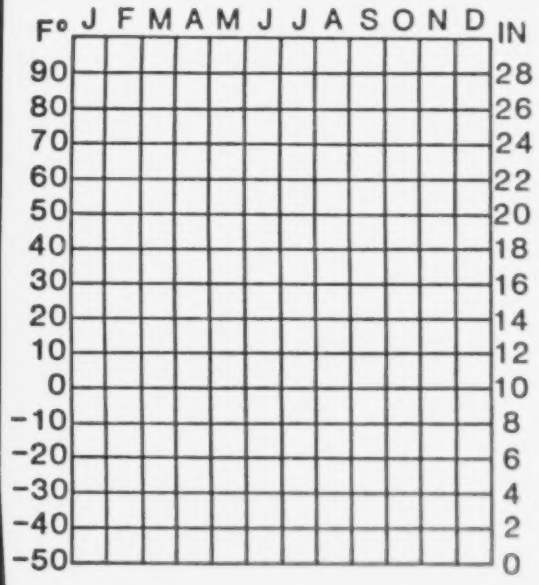

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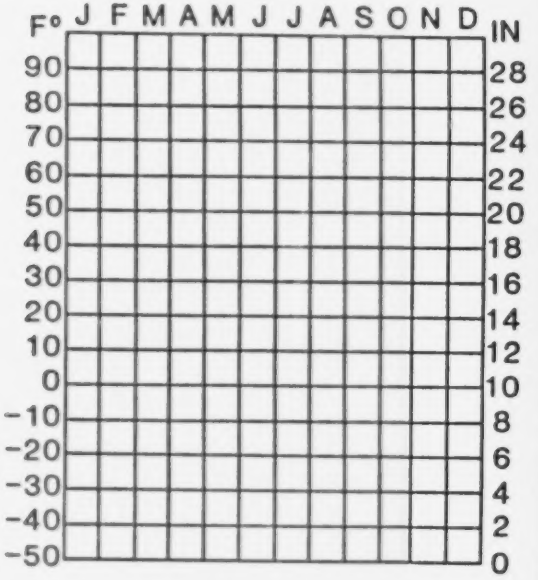

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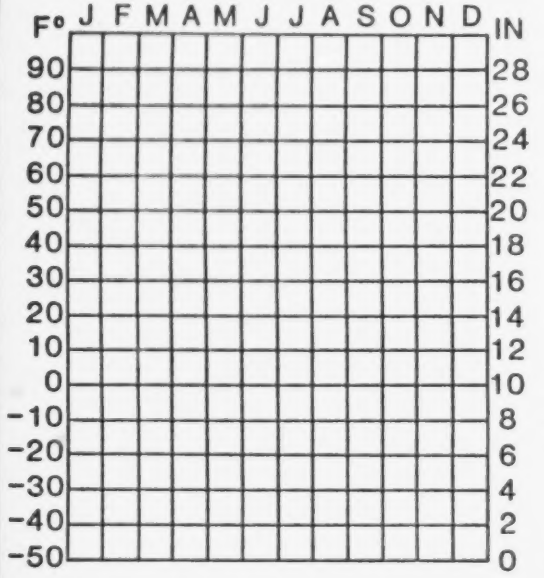
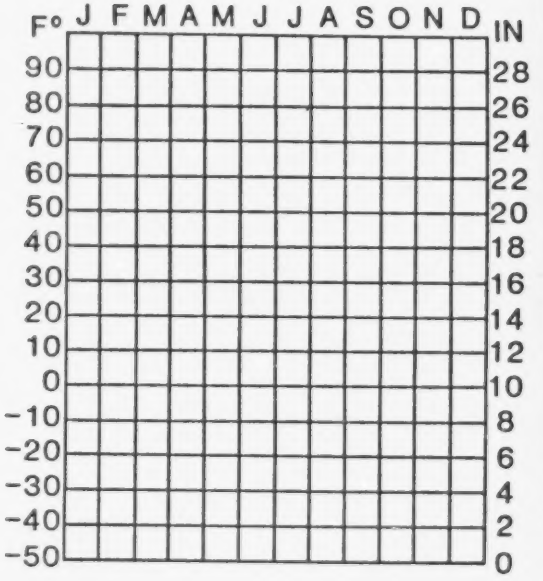


STATION _____



Version D

1. Color in the climate regions on a blank Climates of the World map (e.g. Geocart Series map #100) according to the colors indicated in the legend. Also color in the legend boxes appropriately.

2. Locate the NINE climate stations from the list and write in their names and locations on the climate map. Also write in their names on the climographs.

3. Add up the monthly temperatures for each station and divide the totals by twelve to get the annual mean temperature. Write in the annual mean temperature on the appropriate climographs where it indicates mean temperature.

4. Subtract the lowest monthly mean from the highest monthly mean temperature for each of the nine climates to get the annual range of temperature. Write in the annual range of temperature on the climographs.

5. Add up the precipitation amounts for each station and write in the totals on each climograph.

6. Using the list of selected climate statistics, make a graph of temperature for each station on the climographs by placing a red dot in each monthly column to determine the annual march of temperature. Use the scale of temperature along the left-side of the climograph to determine dot placement. Connect all twelve dots with a red line to show the temperature pattern for the station.

7. Using the list of selected climate statistics, make a graph of precipitation for each station by constructing a bar graph in each monthly column on the climographs. Use the precipitation scale along the right-hand side of the climographs and color in the portion of the column indicated for each month's total precipitation. Use a blue pencil to color in the precipitation column to the appropriate height.

8. Use the Climates of the World map and write in the descriptive climate name for each station's location on the map on the bottom of the climographs where it indicates description. You should identify nine different types of climate.

9. Describe the types of soils and vegetation associated with each of the types of climate you identify and write in these types on the bottom of the climographs where indicated. Use the soil and vegetation maps in the textbook to determine the names of the types by comparing the locations of the climate stations with the maps in the textbook.

10. Indicate the name of the continent or island that each of the climate stations is located on and place the name on the bottom of the climographs where indicated.

CLIMATIC DATA FROM SELECTED STATIONS

Warsaw, Poland

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
T	26	29	35	46	57	63	66	64	56	46	36	30
P	1.2	1.1	1.3	1.5	1.9	2.6	3.0	2.9	1.9	1.6	1.5	1.5

Singapore, Malaya

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
T	78	79	80	81	81	81	81	81	80	80	79	79
P	8.5	6.1	6.5	6.9	7.2	6.7	6.8	8.5	7.1	8.2	10.0	10.4

Denver, Colorado

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
T	30	32	39	47	57	67	72	71	62	51	39	32
P	0.4	0.5	1.0	2.1	2.4	1.4	1.8	1.4	1.0	1.0	0.6	0.6

Archangel, U.S.S.R.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
T	8	9	18	30	41	53	60	56	46	34	22	12
P	0.9	0.7	0.8	0.7	1.2	1.8	2.4	2.4	2.2	1.6	1.2	0.9

Foochow, China

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
T	48	50	58	68	74	80	83	86	77	68	59	50
P	0.7	0.9	1.3	4.0	5.3	6.7	5.3	4.4	5.8	4.6	2.0	0.9

Madrid, Spain

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
T	41	44	48	54	61	69	77	76	68	57	48	40
P	1.3	1.3	1.6	1.7	1.7	1.3	0.4	0.6	1.5	1.8	1.9	1.4

Paris, France

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
T	37	39	43	51	56	62	66	64	59	51	43	37
P	1.4	1.1	1.4	1.5	1.9	2.1	2.0	1.9	1.9	2.1	1.9	1.6

Phoenix, Arizona

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
T	51	54	60	69	77	86	91	89	84	72	59	53
P	0.7	0.8	0.7	0.3	0.1	0.1	0.8	1.1	0.7	0.5	0.5	0.8

Cuiaba, Brazil

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
T	81	80	81	80	75	72	73	75	79	82	81	81
P	9.6	8.9	8.1	4.1	2.0	0.3	0.2	1.1	2.0	4.4	6.0	7.9

Pt. Barrow, Alaska

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
T	-20	-13	-13	-02	22	35	41	39	32	16	0	-15
P	0.1	0.4	0.2	0.3	0.3	0.8	0.3	0.9	0.5	0.7	0.3	0.4

Bulawayo, Zimbabwe

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
T	72	70	69	66	61	57	57	61	68	72	73	72
P	5.9	4.0	3.1	0.6	0.3	0.0	0.0	0.0	0.1	0.9	3.3	5.2

Aswan, Egypt

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
T	62	65	73	81	89	92	93	92	89	85	75	65
P	0.1	0.1	0.1	T	T	T	0.0	0.0	0.0	T	0.1	0.1

CLIMATIC DATA FROM SELECTED STATIONS

N'Djamena (Fort Lamy), Chad

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
T	75	78	86	92	89	86	81	79	82	84	82	79
P	0.0	0.0	0.0	0.1	1.4	4.8	5.1	7.2	1.7	1.5	0.0	0.0

Dublin, Ireland

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
T	40	41	42	45	49	55	58	57	54	48	44	41
P	2.2	1.9	1.9	1.9	2.1	2.0	2.6	3.1	2.0	2.6	2.9	2.5

Kashgar, China

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
T	22	34	47	61	70	77	80	76	59	56	40	26
P	0.3	0.0	0.2	0.2	0.8	0.4	0.3	0.7	0.3	0.0	0.0	0.2

Athens, Greece

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
T	48	49	53	59	68	76	81	81	74	67	58	51
P	2.2	1.5	1.4	0.8	0.8	0.6	0.2	0.4	0.6	1.7	2.8	2.7

Helena, Montana

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
T	20	23	32	44	52	60	68	57	56	45	33	25
P	0.9	0.6	0.8	1.1	2.1	2.3	1.1	0.7	1.2	0.9	0.7	0.8

Karachi, Pakistan

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
T	65	68	75	81	85	87	84	82	82	80	74	67
P	0.6	0.3	0.1	0.1	0.0	0.4	3.2	1.8	0.7	0.0	0.2	0.2

Pt. Barrow, Alaska

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
T	-20	-13	-13	-02	22	35	41	39	32	16	0	-15
P	0.1	0.4	0.2	0.3	0.3	0.8	0.3	0.9	0.5	0.7	0.3	0.4

Moscow, U.S.S.R.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
T	12	15	23	38	53	62	66	63	52	40	28	17
P	1.7	0.9	1.2	1.5	1.9	2.0	2.8	2.9	2.2	1.4	1.6	1.5

Darwin, Australia

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
T	84	83	84	84	82	79	77	79	83	85	86	85
P	15.9	12.9	10.1	4.1	0.7	0.1	0.1	0.1	0.5	2.2	4.8	10.3

Buenos Aires, Argentina

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
T	74	73	69	61	55	50	49	51	55	60	66	71
P	3.1	2.7	4.4	3.5	2.9	2.5	2.2	2.5	3.0	3.5	3.1	3.9

Ft. Simpson, Canada

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
T	-18	-10	+1	26	45	57	62	57	46	29	+4	-12
P	0.7	0.7	0.5	0.7	1.4	1.5	2.0	1.5	1.3	1.1	0.9	0.8

Iquitos, Peru

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
T	78	78	76	77	76	74	74	76	76	77	78	78
P	10.2	9.8	12.2	6.5	10.0	7.4	6.6	4.6	8.7	7.2	8.4	11.5

CLIMATIC DATA FROM SELECTED STATIONS

Freetown, Sierra Leone

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
T	80	81	82	82	82	81	79	78	79	80	80	81
P	0.5	0.1	0.5	2.2	6.3	11.9	35.2	35.5	24.0	12.2	5.2	1.6

Irkutsk, U.S.S.R.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
T	-5	1	17	37	48	59	65	60	48	33	13	1
P	0.6	0.5	0.4	0.6	1.2	2.3	2.9	2.4	1.6	0.7	0.6	0.8

Portland, Oregon

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
T	39	42	46	51	57	61	67	66	61	54	46	41
P	6.7	5.5	4.8	3.1	2.3	1.6	0.6	0.6	1.9	3.3	6.5	6.9

Salt Lake City, Utah

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
T	28	33	40	50	58	67	76	74	65	53	38	32
P	1.4	1.2	1.6	1.8	1.4	1.0	0.6	0.9	0.5	1.2	1.3	1.

Chicago, Illinois

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
T	26	27	37	47	58	68	74	73	66	55	42	30
P	2.1	2.1	2.6	2.9	3.6	3.3	3.4	3.0	3.1	2.6	2.4	2.1

Cairo, Egypt

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
T	55	57	63	70	76	80	82	82	78	74	65	58
P	0.4	0.2	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2

Padang, Sumatra, Indonesia

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
T	79	80	79	80	80	79	79	79	79	79	79	79
P	13.5	9.9	11.9	14.0	12.6	13.0	11.8	13.7	16.1	20.0	20.7	19.4

Los Angeles, California

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
T	53	54	56	58	61	65	67	69	67	62	58	55
P	3.0	3.3	2.8	1.0	0.4	0.1	0.0	0.0	0.2	0.6	1.1	2.9

Pt. Barrow, Alaska

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
T	-20	-13	-13	-02	22	35	41	39	32	16	0	-15
P	0.1	0.4	0.2	0.3	0.3	0.8	0.3	0.9	0.5	0.7	0.3	0.4

Shanghai, China

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
T	39	40	47	58	68	74	82	82	74	65	54	44
P	1.9	2.3	3.3	3.7	3.7	7.1	5.8	5.6	5.1	2.8	2.0	1.4

Santa Cruz, Argentina

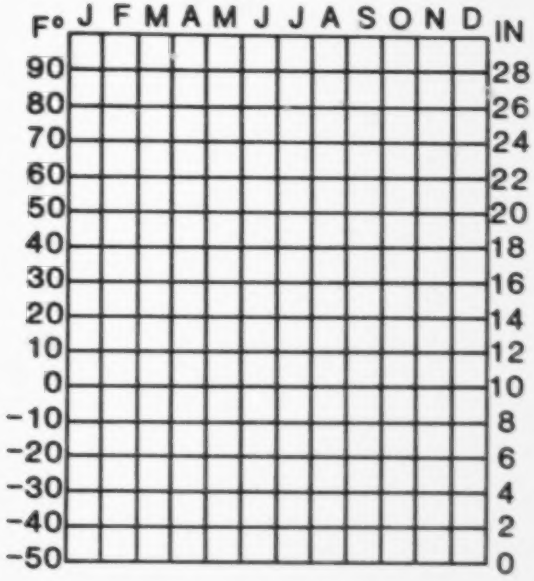
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
T	59	58	55	48	41	35	35	38	44	49	53	56
P	0.6	0.4	0.3	0.6	0.6	0.5	0.7	0.4	0.2	0.4	0.5	0.9

Kimberley, South Africa

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
T	76	74	70	63	55	49	49	54	61	67	71	75
P	2.8	3.1	3.0	1.3	0.9	0.3	0.4	0.4	0.7	1.0	1.7	2.4

CLIMOGRAPHS

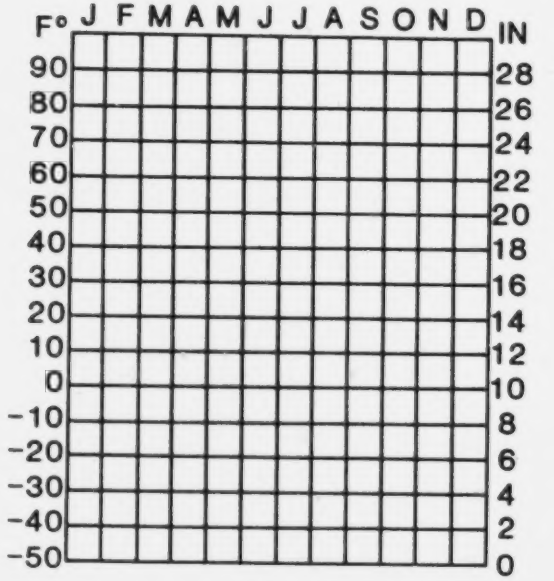
STATION _____
MEAN TEMP. _____
TEMP. RANGE _____
TOTAL PPT _____



KÖPPEN: _____

DESCRIPTION: _____
VEGETATION: _____
SOIL: _____
CONTINENT: _____

STATION _____
MEAN TEMP. _____
TEMP. RANGE _____
TOTAL PPT _____

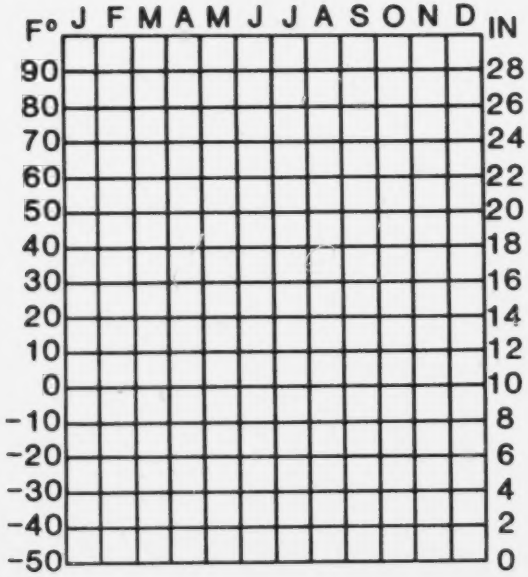


KÖPPEN: _____

DESCRIPTION: _____
VEGETATION: _____
SOIL: _____
CONTINENT: _____

CLIMOGRAPHS

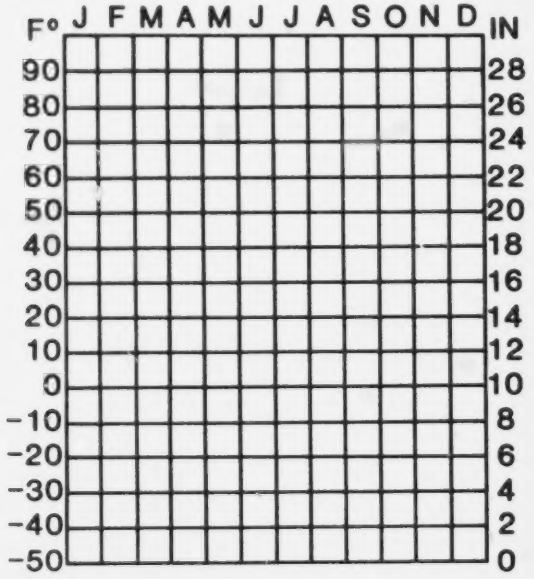
STATION _____
MEAN TEMP. _____
TEMP. RANGE _____
TOTAL PPT _____



KÖPPEN: _____

DESCRIPTION: _____
VEGETATION: _____
SOIL: _____
CONTINENT: _____

STATION _____
MEAN TEMP. _____
TEMP. RANGE _____
TOTAL PPT _____

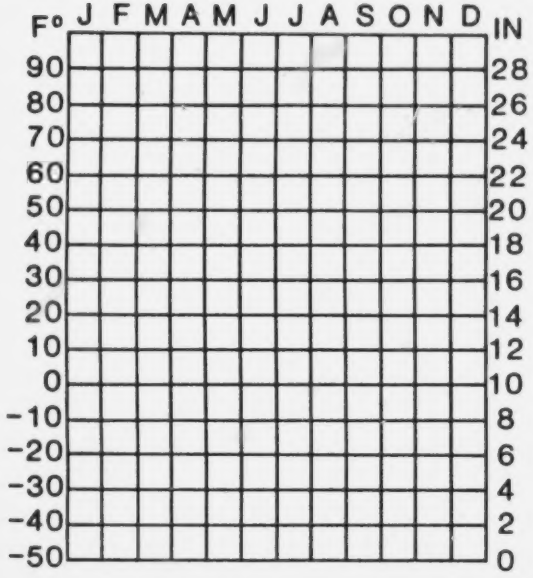


KÖPPEN: _____

DESCRIPTION: _____
VEGETATION: _____
SOIL: _____
CONTINENT: _____

CLIMOGRAPHS

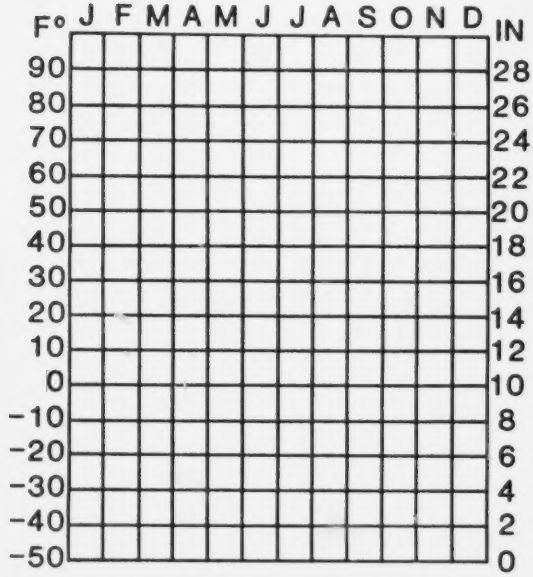
STATION _____
MEAN TEMP. _____
TEMP. RANGE _____
TOTAL PPT _____



KÖPPEN: _____

DESCRIPTION: _____
VEGETATION: _____
SOIL: _____
CONTINENT: _____

STATION _____
MEAN TEMP. _____
TEMP. RANGE _____
TOTAL PPT _____

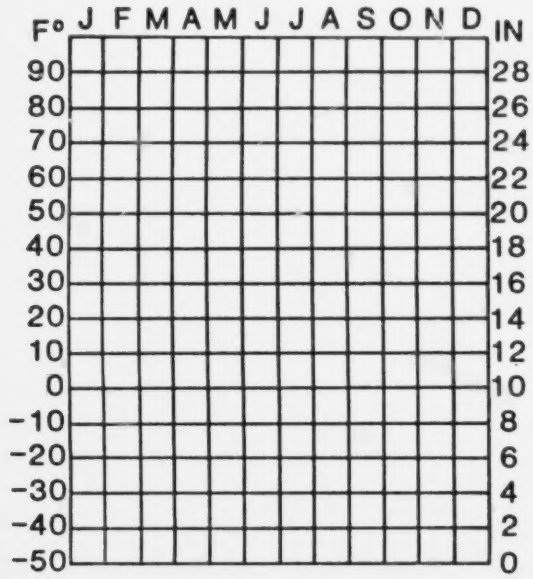


KÖPPEN: _____

DESCRIPTION: _____
VEGETATION: _____
SOIL: _____
CONTINENT: _____

CLIMOGRAPHS

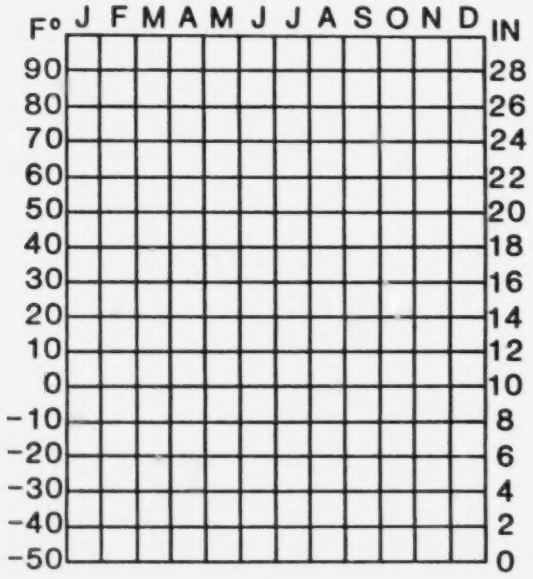
STATION _____
MEAN TEMP. _____
TEMP. RANGE _____
TOTAL PPT _____



KÖPPEN: _____

DESCRIPTION: _____
VEGETATION: _____
SOIL: _____
CONTINENT: _____

STATION _____
MEAN TEMP. _____
TEMP. RANGE _____
TOTAL PPT _____

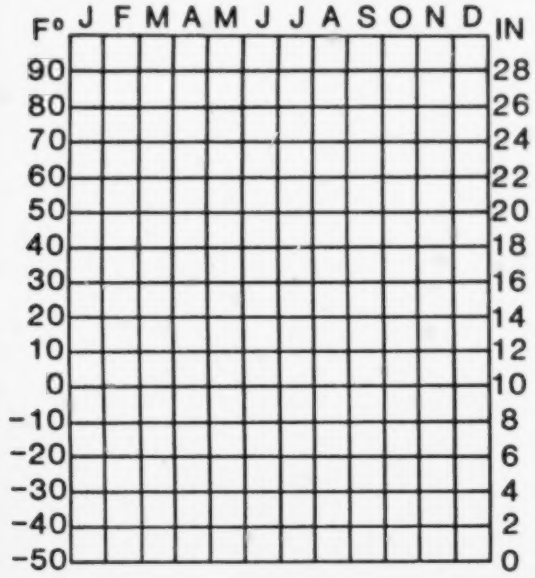


KÖPPEN: _____

DESCRIPTION: _____
VEGETATION: _____
SOIL: _____
CONTINENT: _____

CLIMOGRAPHS

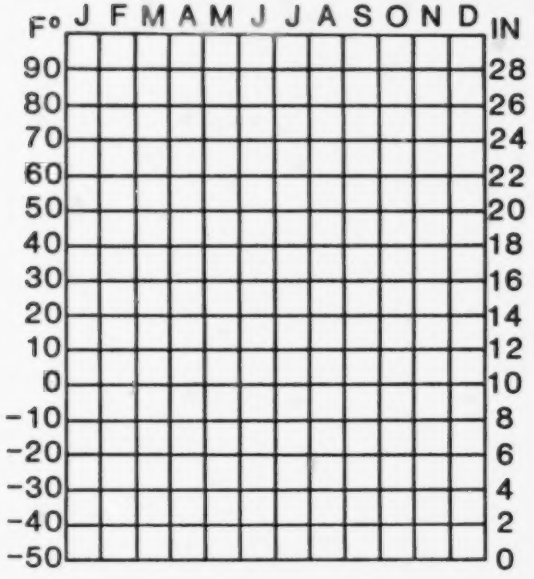
STATION _____
MEAN TEMP. _____
TEMP. RANGE _____
TOTAL PPT _____



KÖPPEN: _____

DESCRIPTION: _____
VEGETATION: _____
SOIL: _____
CONTINENT: _____

STATION _____
MEAN TEMP. _____
TEMP. RANGE _____
TOTAL PPT _____



KÖPPEN: _____

DESCRIPTION: _____
VEGETATION: _____
SOIL: _____
CONTINENT: _____

SOILS

8. SOIL COMPONENTS AND CHARACTERISTICS

Soils is not an area heavily stressed in most introductory physical geography courses. This is not for lack of interest or a feeling that soil and soil development is not a significant topic. Instead, it reflects the general pattern and certainly the one followed at UCLA that soil and vegetation is a topic usually dealt with in detail in a biogeography course. It is, however, essential that students have the basic principles in mind, particularly those that relate to soil-hydrologic relationships. The following exercise is intended to deal with that question in a very elementary way.

Topics to be covered

Textural categories

Storage areas in the soil

Basic terms such as bulk density, field capacity, available water

Naming of soils

Version A

You have been given the following measurements on a particular soil sample of interest:

Dry weight of soil sample, 10 grams
Wet weight of soil sample, 14 grams
Volume of soil sample, 20 cm^3
Permanent wilting percentage, 20%

Using the following formulas, calculate the following:

Bulk density = $\frac{\text{dry weight of soil}}{\text{volume}}$

Field capacity = $\frac{\text{weight of water in wet soil sample}}{\text{weight of dry soil sample}}$

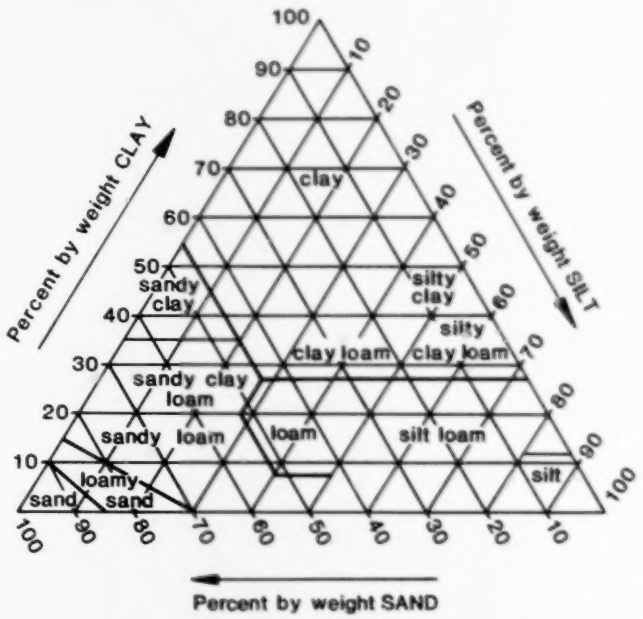
Available water = field capacity - permanent wilting percentage

Bulk density _____

Field capacity _____

Available water _____

Based on the field capacity and available water of this soil sample, it is most likely that this soil consists mostly of _____ (sand, silt, clay).



What is the name of the soil that consists of 10 percent sand particles, 45 percent silt particles, and 45 percent clay particles?

HYDROLOGY

9. RATING CURVES AND RECURRENCE INTERVALS

Of all the areas of physical geography, with perhaps the exception of energy balance climatology, the field of hydrology tends to present students with the greatest difficulty. This is true not so much of the basic concepts such as that of the hydrologic cycle as it is of the application of hydrologic principles in terms of rating curves, flood frequency curves, etc. For introductory situations, it is essential that the often complex equations associated with many questions of flood routing, hydrograph separation and flood frequency predictions be minimized and only the basic versions of such equations and concepts be presented. Accordingly, the following exercises rely upon only basic and relatively straightforward and quite basic equations and concepts.

Concepts to cover:

Hydrologic cycle

Rating curves and stream flow

Flood frequency curves

Use of hydrologic data in planning

Use of logarithmic scales and plotting procedures for data

A more detailed discussion of specific concepts

A rating curve relates height of the water to stream discharge, and so makes discharge estimates easy if the height of the water is measured.

A flood frequency curve shows the average number of years between times a particular discharge is equaled or exceeded. As a planning tool, it allows estimates to be made of the flooding potential of a particular site.

Both curves are susceptible to error from short sample times and changes in the hydrologic system--damming, urbanization, fires, forest clearing, etc. Extrapolating the curves beyond the values included in the data set is risky, too.

Version A

A rating curve relates stream discharge (Q) to the height of the water surface above some arbitrary datum called the stage.

1. Reading off the rating curve, what gage height is associated with a discharge of:

   20 cms _____
   60 cms _____
   400 cms _____

2. What is the discharge if the stage is:

   5.0 meters _____
   7.5 meters _____
   8.5 meters _____

A flood frequency curve relates discharge to the average number of years between times when that discharge is equaled or exceeded. That is, a flood with a recurrence interval (RI) of five years will be equaled or exceeded, on the average, once every five years or four times in twenty years. The recurrence interval is determined by the formula:

$$RI = \frac{N + 1}{M}$$

Where N is the number of years of record, and M is the rank of the given flood in the list of annual floods.

3. Use the flood frequency curve to estimate the recurrence interval of a flood of the following magnitude:
   100 cms _____
   200 cms _____
   300 cms _____

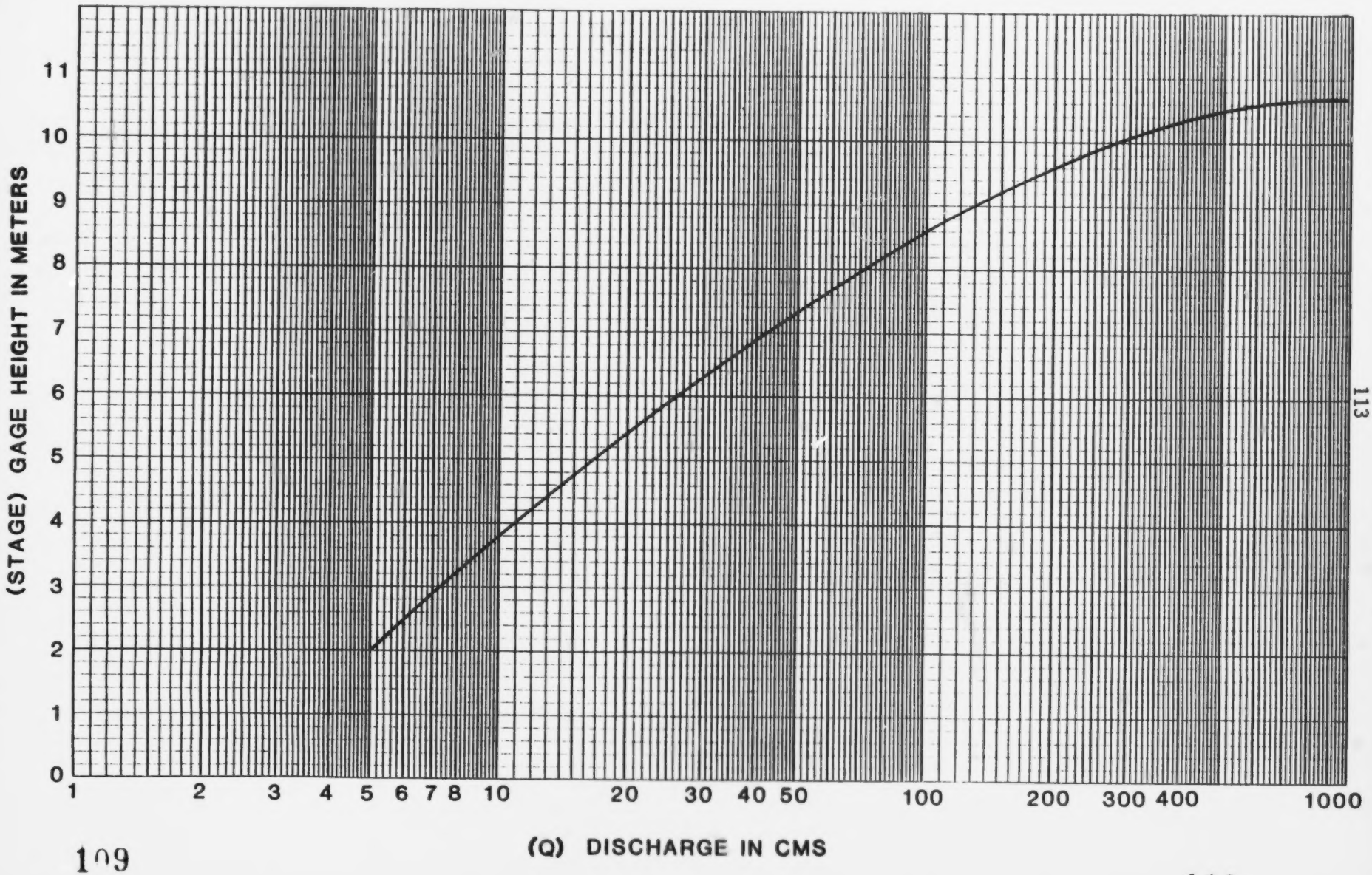
4. What is the discharge of the:
   50 year flood _____
   100 year flood _____
   500 year flood _____

5. What is the stage of the: 50 year flood _____, 300 year flood _____?

6. What is the recurrence interval of the flood stage of: 9 meters _____, 10 meters _____?

7. If you wanted to build a house to be safe from the twenty-five year flood, at what elevation above the arbitrary datum would you build? _____

8. If a good friend of yours wanted to buy a house that was 8 meters above the datum, would you recommend it (the house was recently built)? _____ Why?


RATING CURVE
(STAGE) GAGE HEIGHT IN METERS
0
1
2
3
4
5
6
7
8
9
10
11
1
2
3
4
5
6
7
8
10
20
30
40
50
100
200
300
400
1000
(Q) DISCHARGE IN CMS

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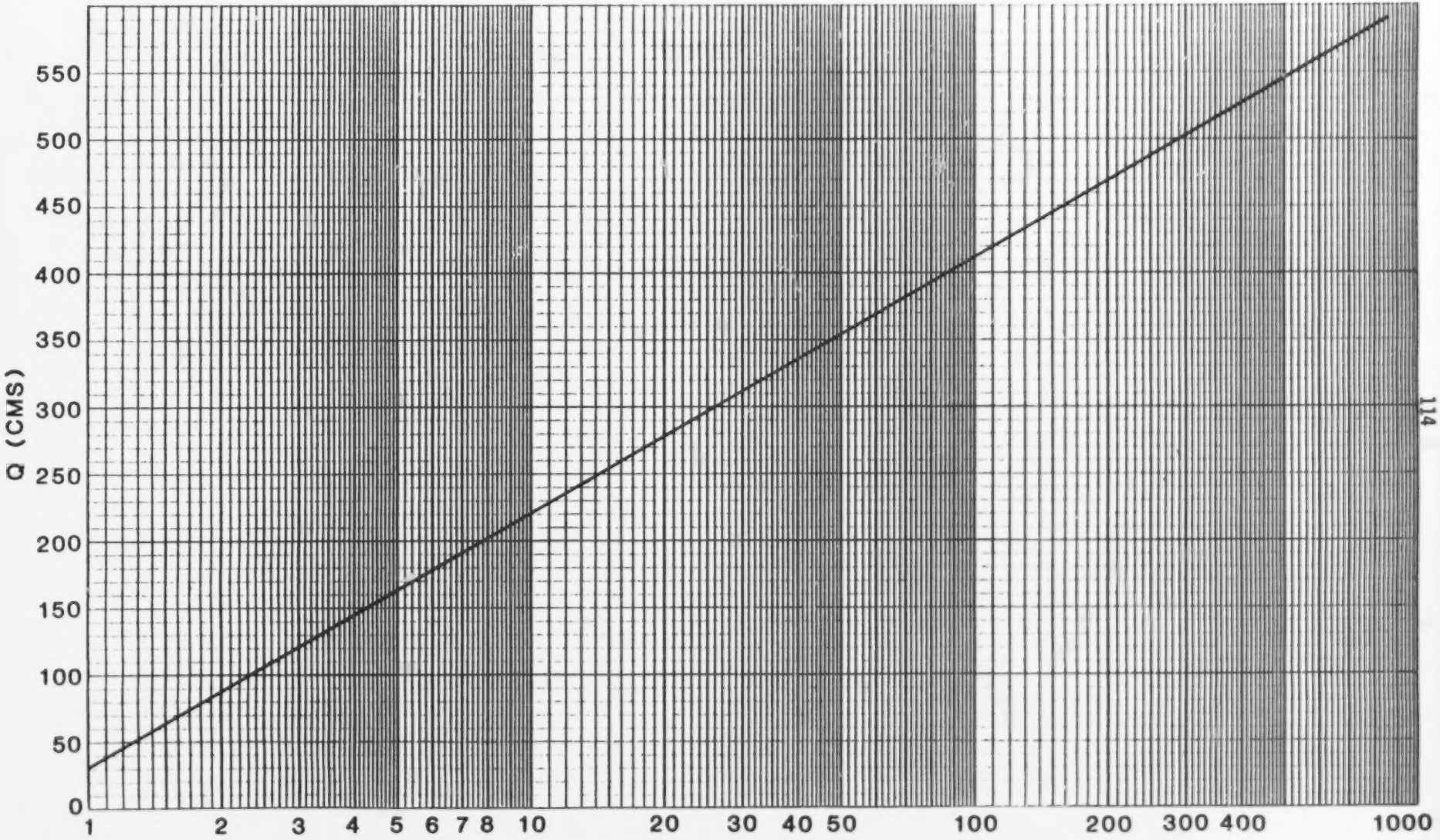
FLOOD FREQUENCY CURVE



111

112

114

Version B

A rating curve **relates** stream **discharge** (Q) to the height of the water surface above some arbitrary **datum called the** stage. The following data are discharge calculations obtained at a **gaging station. Plot the gage height** (stage) against discharge on the logarithmic paper labeled "rating **curve.**" Then draw a smooth-curved line through the points representing the rating curve for this station.

Stage (meters)	Discharge (Q) (cms)
2.0	5
3.4	8
4.0	10
6.5	25
7.1	35
7.8	50
8.2	71
8.8	110
9.2	175
9.6	250
10.1	500
10.4	900

1. Reading off the rating curve, what gage height is associated with a discharge of:
   20 cms _____
   60 cms _____
   400 cms _____

2. What is the discharge if the stage is:
   5.0 meters _____
   7.5 meters _____
   8.5 meters _____

A flood frequency curve relates discharge to the average number of years between times when that discharge is equaled or exceeded. That is, a flood with a recurrence interval (**RI**) of five years will be equaled or exceeded, on the average, once every five years, or four times in twenty years. The recurrence interval is determined by the formula

$$RI = \frac{N + 1}{M}$$

Where N is the number of years of record, and M is the rank of the given flood in the list of annual floods. The following is a list of annual maximum floods at a gaging station for fifteen years.

YEAR	PEAK Q (cms)	RANK (M)	RI = (N + 1)/M
1965	65	_____	_____
1966	38	_____	_____
1967	142	_____	_____
1968	80	_____	_____
1969	165	_____	_____
1970	200	_____	_____
1971	55	_____	_____
1972	35	_____	_____
1973	75	_____	_____
1974	90	_____	_____
1975	110	_____	_____
1976	255	_____	_____
1977	125	_____	_____
1978	58	_____	_____
1979	60	_____	_____

Assign rank numbers to the discharges (1 for the largest flood, 15 for the smallest), calculate the recurrence interval, and plot **RI** versus Q on the logarithmic paper labeled "flood frequency curve." **Draw a** straight line through the points.

3. Use your flood frequency curve to estimate the recurrence interval of a flood of the following magnitude:
   100 cms _____
   200 cms _____
   300 cms _____

4. What is the **discharge** of the:
   50 year flood _____
   100 year flood _____
   500 year flood _____

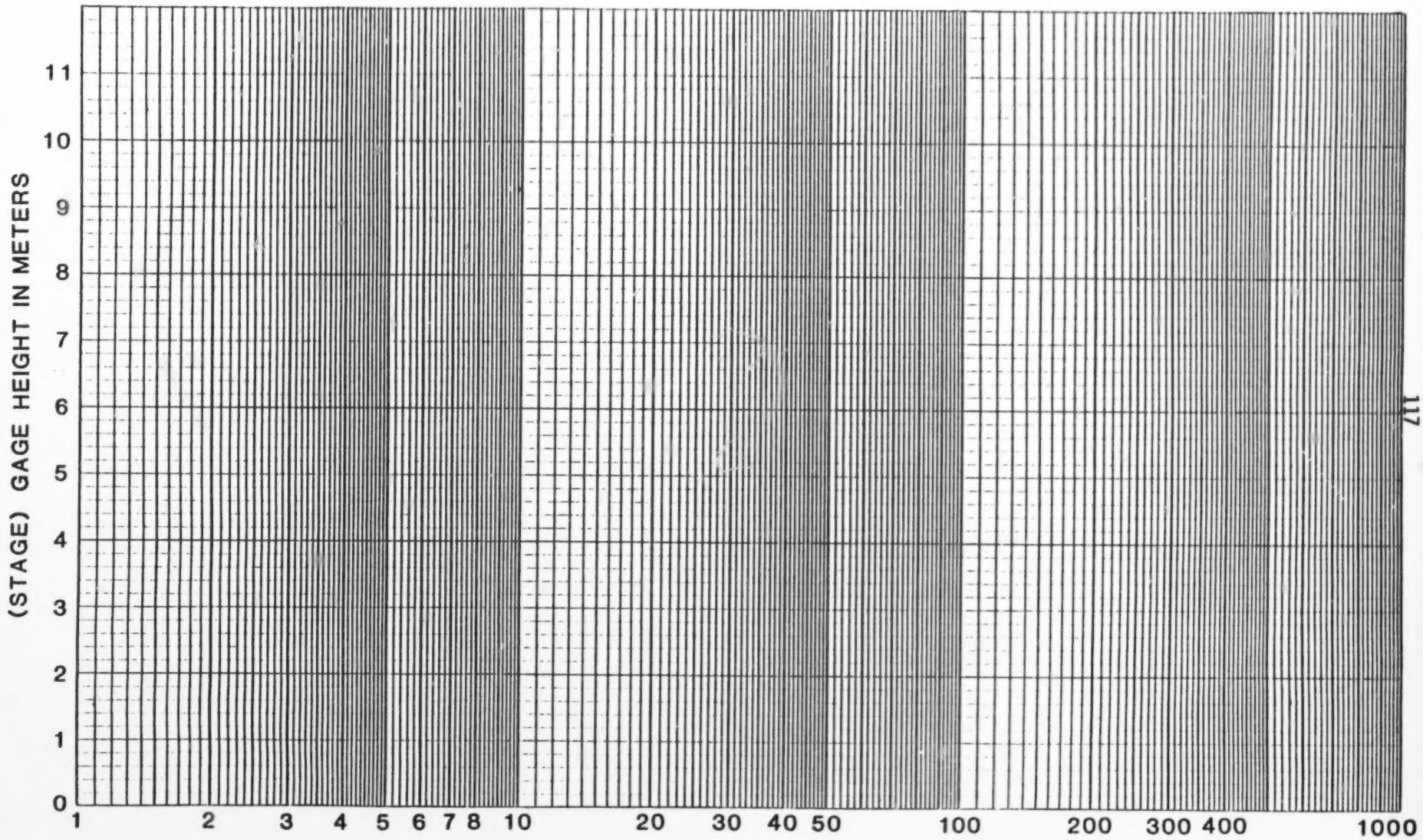
5. What is the stage of the:
   50 year flood _____ 300 year flood _____

6. What is the recurrence interval of the flood stage of:
   9 meters _____ 10 meters _____

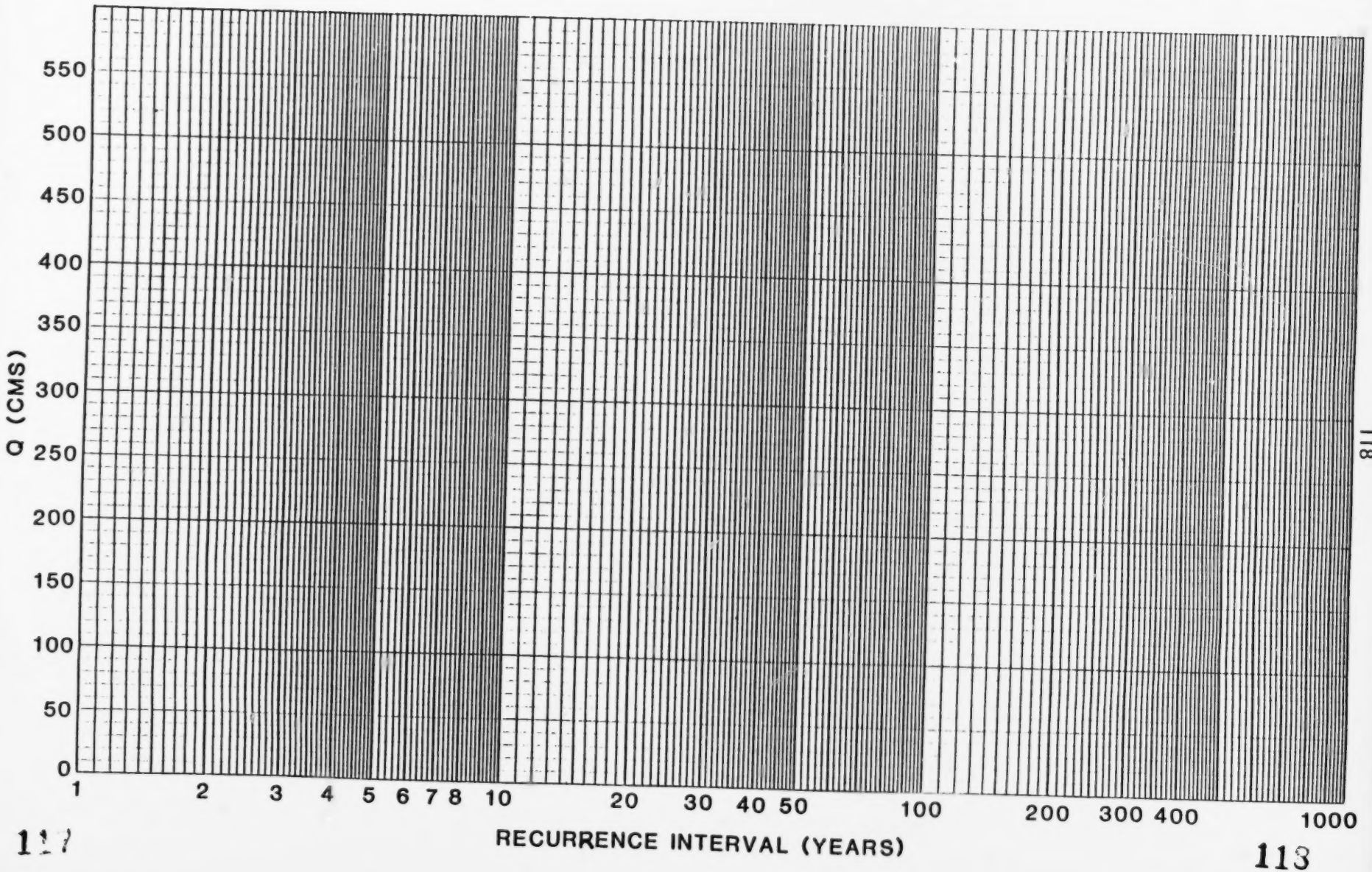
7. If you wanted to build a house to be safe from the twenty-five year flood, at what elevation above the arbitrary datum would you build? _____

8. If a good friend of yours wanted to buy a house that was eight meters above the datum, would you recommend it (the house was recently built)? _____
   Why?

RATING CURVE



FLOOD FREQUENCY CURVE



Version C

You are working for the U.S. Forest Service in the Los Padres National Forest. There has recently been a fire in Bear Canyon which has burned most of the watershed. Fortunately, there is a stream gaging station located at Webber Ranch and good records of the stream flow are available. You decide this would be a perfect opportunity to study the hydrologic response of the watershed in a post fire situation. Obtain a copy of the Tepusquet Peak quadrangle and a piece of tracing paper.

1. Trace the Bear Canyon drainage basin boundaries and all the marked streams within the watershed north of Webber Ranch. Also, trace the grid system off the topographic sheet where it covers the watershed. Your finished map should include:
   (a) the watershed boundaries
   (b) all of the intermittent streams within the watershed
   (c) the grid system covering the watershed
   (d) a metric linear scale
   (e) the representative fraction scale
   (f) a title for your map
   (g) a north arrow

2. Looking at the key to the map, what kind of vegetation has burned?

3. Calculate the gradient of the stream from the upstream end of the most northerly tributary to Webber Ranch (use feet per mile) _____ feet/mile.

4. In order to study the effects of the fire on the watershed and how the flow characteristics of the stream change as the vegetation recovers, you will need to plot a rating curve for the stream. A rating curve relates stream discharge (Q) to the height of the water surface above some arbitrary datum. The following data are discharge measurements obtained from the gaging station at Webber Ranch.

   Plot the gage height (called the stage) against discharge on the logarithmic paper labeled RATING CURVE FOR BEAR CREEK. Then draw a line through the points representing the rating curve for this station.

STAGE (gage height in feet)	DISCHARGE (Q in ft. 3/second)
3.25	1.8 (c.f.s.)
4.60	2.9
5.08	3.6
5.45	4.0
6.10	5.6
6.90	9.5
7.30	16.0
7.65	18.0
8.45	33.0
9.35	53.0
9.50	86.0
10.80	320.0

5. What is the gage height associated with a discharge of:
   (a) 1.2 c.f.s. _____
   (b) 8.0 c.f.s. _____
   (c) 200 c.f.s. _____

6. What is the discharge if the gage height shows a water surface elevation of:
   (a) 4.2 feet _____
   (b) 6.5 feet _____
   (c) 8.0 feet _____

   Now, by simply reading the gage height from a stage recorder you can get a good estimation of the discharge following any precipitation event. Having this data you can then compare pre-fire and post-fire responses and see how the flow characteristics have changed due to the lack of vegetation.

   After a fire there is usually more overland flow and less infiltration due to the lack of vegetation. This results in more erosion and greater flood peaks. Because more water is now being carried out of the watershed through the channels, the drainage network should also expand and there should be an increase in the drainage density.

   Because you expect more flooding to occur after the fire (until the vegetation recovers), you decide you would like to know the recurrence interval of floods if conditions were normal.

7. A flood frequency curve relates discharge to the average number of years between times when that discharge is equaled or exceeded. That is, a flood with a recurrence interval (RI) of five years will be equaled or exceeded, on the average, once every five years or four times in twenty years. Recurrence interval is determined by the formula:

$$RI = \frac{N + 1}{M}$$

   Where N is the number of years of record and M is the rank of the given flood in the list of annual floods. The following is a list of annual maximum floods for Bear Creek for a fifteen year period.

Year	Peak discharge (CFS)	Rank	(N+1)/M = RI
1965	250		
1966	160		
1967	70		
1968	300	3	5.3
1969	210		
1970	60		
1971	20		
1972	460	1	16
1973	330	2	8
1974	180		
1975	45		
1976	55		
1977	270		
1978	50		
1979	140		

   Assign rank numbers to the discharges (1 for the largest flood, 15 for the smallest), calculate the recurrence interval, and plot RI versus Q (c.f.s.) on the logarithmic paper labeled FLOOD FREQUENCY CURVE FOR BEAR CREEK.

8. Use your flood frequency curve to estimate the recurrence interval of a flood of the following magnitude:
   (a) 100 c.f.s. _____
   (b) 200 c.f.s. _____
   (c) 400 c.f.s. _____
   (d) 550 c.f.s. _____

9. What is the recurrence interval of a flood stage of:
   (a) 9 feet _____
   (b) 10.2 feet _____

10. If you wanted to build a Forest Service station to be safe from the twenty-five year flood, at what elevation above the arbitrary datum would you build? _____

11. What is the discharge of the twenty-five year flood? _____

The following questions refer to your map.

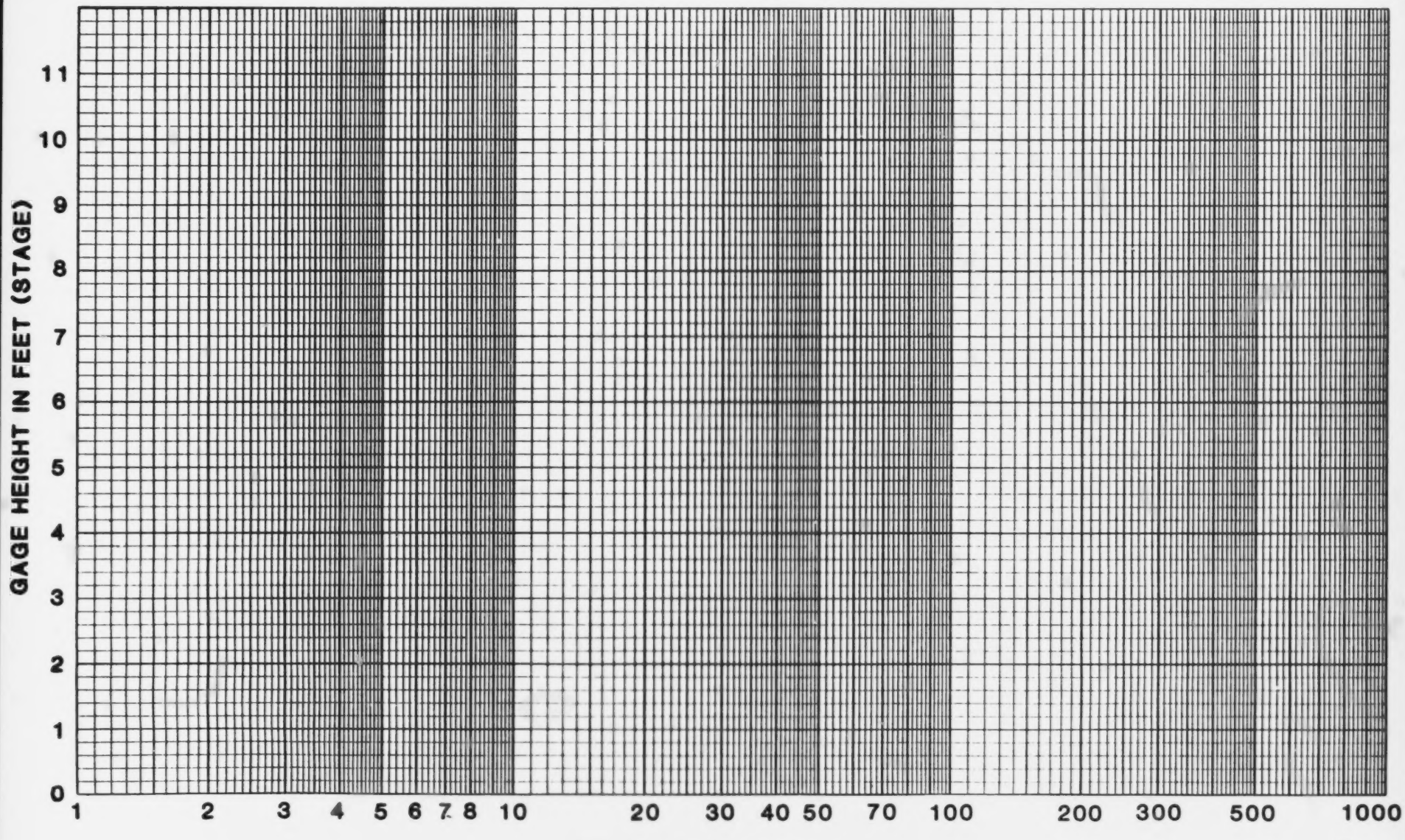
12. Each square on the grid over your watershed is one square kilometer. Estimate the area of the watershed in square kilometers. _____ km^2.

13. Measure the total stream length (the total length of all the streams combined) in kilometers. _____ km

14. Calculate the pre-fire drainage density of the watershed by dividing the total stream length by the area of the watershed. Drainage density equals _____ km/km^2

15. From aerial photos taken after the fire, the drainage density was calculated to be 2 km/km^2. Has the drainage density increased or decreased? _____

BEAR CREEK RATING CURVE



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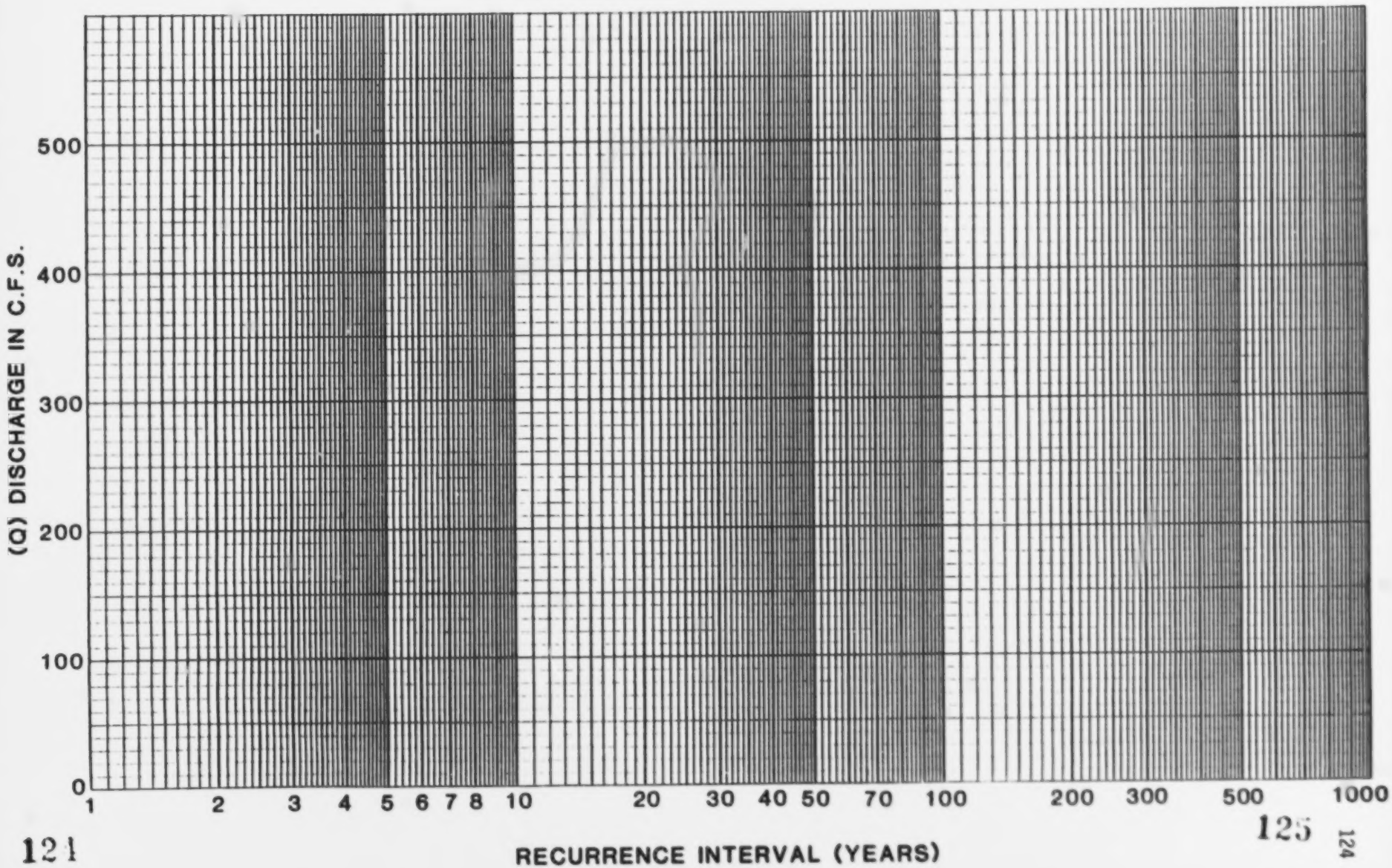
FLOOD FREQUENCY CURVE FOR BEAR CREEK



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TOPOGRAPHIC MAPS AND GEOMORPHIC PROCESSES

10. APPLICATIONS OF TOPOGRAPHIC MAPS IN SPECIFIC SUBFIELDS

This final group of laboratory exercises contains material related to several subareas of physical geography. Most rely upon the use of topographic maps and a thorough understanding of basic geomorphic features to allow interpretation of fluvial, glacial, and coastal or structural environments or settings.

(A) Fluvial Processes

Version A

CHULAR

The Chular quadrangle, showing an area in central California, was prepared by the Army Map Service--not the U.S. Geological Survey. Note the legend at the bottom. This map can be divided into the mountainous region in the southwest, the floodplain of the meandering Salinas River in the center, and an alluvial fan in the northeast.

We all know that small streams flow into bigger streams which flow into bigger streams, etc., until the water reaches the ocean, right? Do streams enter the Salinas River in this fashion? _____ Why might this be so? _____

Is the Salinas dry part of the year? _____

At the most northerly extent of the Salinas River is a landform commonly associated with alluvial rivers. If this feature were filled with water, what would it be called? _____

Look at the mountainous portion of the map. Does the shrubland ("brushwood") tend to be on the north or south sides of the mountains? _____ How does the direction a slope is facing (called aspect) affect the amount of water available to plants (hint: you probably won't find this in the book--think of sun angles and evaporation)? _____

In the 1940's when this map was prepared, the town of Chular had one school, one church, some sort of railway station, and a water tower. Would you like to have lived there then? (Hint: put either "yes" or "no".) _____

Version B

I. Fluvial Erosion

A. From your map folder remove the following maps: **Malaga**, Washington; New Haven, Illinois; and **Bright Angel, Arizona.** On these maps find and compare (as to the following) the Colorado, Wabash, and Columbia rivers.

	COLUMBIA	WABASH	COLORADO
1. Gradient (steep, moderate, flat)	_____	_____	_____
2. Meanders (many, few, none)	_____	_____	_____
3. Floodplain (none, narrow, wide)	_____	_____	_____
4. Valley Shape ("V", "U", broad, flat)	_____	_____	_____
5. Other (oxbows, water-falls, rapids)	_____	_____	_____
6. Stage (youth, mature, old age)	_____	_____	_____

B. On any of the remaining maps, locate a good example of a youthful, mature, and old age stream. Have your results checked with the lab instructor:

Youth _____
(Map and stream name)

Mature _____
(Map and stream name)

Old Age _____
(Map and stream name)

C. Divides or Interfluves

Use the following maps to examine the divides or ridges which separate stream valleys and determine the stage of the area in the erosion cycle: Katterskill, New York; Soda Canyon, Colorado; Princeton, Indiana - Illinois; Effingham, Illinois; and New Haven, Illinois - Indiana.

1. Soda Canyon, Colorado: Give the term which describes the topography of the divides in the northwest section of the map, north of Mancos Canyon (use the terms flat, dissected, monadnock). _____

2. Effingham, Illinois: Give the term which best describes the topography of the divides over that part of the map northwest of the Pennsylvania railroad tracks (use terms flat, dissected, monadnock). _____

3. Katterskill, New York: Give the term which best describes the divides located in Greene County. _____

4. New Haven, Illinois - Indiana: Give the term which best describes Dogtown Hills and the hills in Sections 20 and 30 of T7S, R10E. _____

5. Princeton, Indiana - Illinois: Give the term which best describes Orville Hills and Gordon Hills. _____

6. The condition of the divides indicates that:
   A. Soda Canyon area is in a stage of: _____
   B. Effingham, ILL, area is in a stage of: _____
   C. Katterskill, NY, area is in a stage of: _____
   D. New Haven, ILL, and Princeton topographies are in a stage of: _____

II. Floodplains

A. Find the Camden, Missouri, and Campti, Louisiana, maps.

(1) What evidence do you see to substantiate the development of a floodplain by the Missouri River? _____

(2) Please note the swamps in Townships 50 and 51N. Why are these swamps forming in the river valley? _____

(3) Locate a similar situation (both floodplain and swamps in valley) on another map and have it checked by your instructor.

(4) What is the proper geologic name for the lake that almost encircles Smith Island? _____

(5) Locate another lake similar to that one in Question 4 and have your response checked.

III. Peneplains

A. Locate the East Brownsville, Texas, and La Paloma, Texas, maps.

(1) Describe the topography in this region (flat, mountains, etc.). _____
_____

(2) What type of material covers this region? _____

(3) How near base level is this region? _____

(4) What has happened to the hills (mountains) in this region? _____

(5) What is a good geologic name for this floodplain? _____

(6) Locate another map where this type of landform is being produced.

_____
Map

(7) **Find** the Menan Buttes, Idaho map. If you assume that this mapped area is part of a peneplain, explain why the Menan Buttes are or are not monadnocks.

IV. Stream Pattern

A. Locate the following maps: Ennis, Montana; Shasta, California; Effingham, Illinois; Harrisburg, Pennsylvania; Mount Rainier, Washington.

(1) Describe the drainage pattern on the above maps as per given locality. (Use words like trellis, parallel, radial, and dendritic.)

ENNIS _____
T4S, R1W, S22-27

ENNIS _____
T4S, R1E, S17-20, 29-30

SHASTA _____
T41N, R3W

EFFINGHAM _____
Entire map

HARRISBURG _____
Blue Mts NW to Peters Mountain

MT. RAINIER _____
along Silver Creek, SW corner of map

B. Using remaining maps, locate an example of dendritic, trellis, and radial drainage.

DENDRITIC _____
Map and stream name

TRELLIS _____
Map and stream name

RADIAL _____
Map and stream name

V. Landform

Locate the **Ennis**, Montana, and Malaga, Washington, maps.

A. ENNIS, MONTANA

1. Describe the channel feature exhibited by Madison River south of Ennis Lake. _____

2. Which direction is Madison River flowing south of Ennis Lake? Why? _____ _____

B. MALAGA, WASHINGTON

1. What fluvial landform can be found in T21N, R22E, S9, 16, 21, 28, 33? _____ _____

2. How was base level changed to cause the above named feature (raised or lowered)? _____

3. Locate on another map a feature or features that represent a similar base level change. Have your response checked. _____

4. What is the name of the process responsible for the feature mentioned in Question 1? _____

(B) Glacial and Volcanic Processes

Version A

I. MOUNT RAINIER, WASHINGTON, QUADRANGLE

The landforms on this quadrangle are a result of volcanic and glacial processes.

1. Mt. Rainier itself is a _____.

2. Give ~~the~~ names of three arêtes on Mt. Rainier:
   1. _____
   2. _____
   3. _____

3. Give the names of two glaciers on Mt. Rainier which have medial moraines:
   1. _____
   2. _____

4. Give the names of two glaciers on Mt. Rainier which have lateral moraines:
   1. _____
   2. _____

5. Sunset Amphitheater (just west of the summit) is an example of what type of glacial landform? _____

6. Give an example of a valley that was formerly occupied by a glacier (look for a U-shaped valley). _____

7. What type of river is the White River (northeast portion of the quadrangle)? _____

8. What type of bedload is the White River carrying? _____

9. Look at the streams on Mount Rainier. Where do they start? _____
   What type of bedload are they carrying? _____
   What is the source of this load? _____

10. Calculate the slope of North Mowich Glacier (western flank of Mt. Rainier) along its length in feet/miles (show your work). _____

II. KENAI, ALASKA, QUADRANGLE

Name three aspects of the landscape which distinguish this area as a glacial environment. (Other than the glaciers themselves! Look especially at drainage and surface material.)

1. _____
2. _____
3. _____

III. PALMYRA, NEW YORK, QUADRANGLE

The area shown on this map experienced continental glaciation during the Pleistocene epoch. The peculiar landforms shown on this map are related to this glaciation. Using your textbook and what you have learned in class, identify these depositional landforms. (It may help to draw a brief sketch of one of the forms in profile, i.e., sideways.)

_____

In what direction was the ice moving? _____

Version B

For this section you will be asked to use the following topographic maps: Chief Mountain, Montana; Holden, Washington; Holy Cross, Colorado; Mt. Tom, California; Mt. Fairweather, Alaska; Mt. Rainier, Washington; Yosemite Valley, California.

A. Firn Limit

(1) The "firn limit" for a given area is the elevation above which there exists perennial firn (glacial ice).

Using the Mt. Tom, Holden, and Mt. Fairweather maps, determine each respective firn (minimal-lowest) limit.

Mt. Tom	Holden	Mt. Fairweather
_____	_____	_____

(2) What is the approximate latitude for these three areas?

Mt. Tom	Holden	Mt. Fairweather
_____	_____	_____

(3) What relationship is there between firn limit elevation and latitude? Explain.

_____

(4) Using the Holden map, is the lowest firn found on a north facing or south facing slope? _____ north/south. Explain.

_____

(5) If we had a map of the glaciers on Mt. Kenya in East Africa at lat. 0°'02"S, would the firn limit be higher or lower than on the above three maps? Explain.

_____

B. Chief Mountain/Soda Canyon

(1) The Chief Mountain map portrays a portion of a major mountain range in North America. If needed, use your atlas or the wall map to determine which mountain range this is.

_____

(2) What type of glaciation occurred in the area shown by the map? _____

(3) What relationship exists between: (a) the Continental Divide and the presence of glaciers, and (b) the Divide and the direction of water flow?
(a) _____
(b) _____

(4) Locate Camas Creek (west side). What is the proper name for the lakes that are along the valley bottom? _____

(5) What kind of basin contains Bench Lake? _____

(6) What is the proper name for Goat Lake? _____

(7) To answer this question will require you to use the Soda Canyon map also. On the Chief Mountain map, locate Belly River (north-central) and draw a cross section from Ptarmagin Wall northwest to the 7,600 "bench mark" near Mt. Merritt. Use the Soda Canyon map and draw a cross section of Morefield Canyon. Draw from a point due west of the northern boundary of Section 31, T34N. Account for the difference in the cross section.

Cross Section Belly River

Cross Section Morefield Canyon

(8) Locate Mt. Cleveland (approximately 48°55'N - 113°50'W). Nearby are Kaina Lake and White Crow Lake. What types of lakes are these? _____

(9) What is the name of the basin each lake occupies? _____

(10) How many cirques are located on Mt. Reynolds? (48°40'N - 113°41'W) ____
_____

(11) This mountain is known as a _____.

(12) How was it formed? _____

(13) Find Comas Creek on the west margin of the map, follow the creek upstream to Longfellow Peak. What is the proper name for the series of lakes located in the valley? _____

(14) In which directions did Blackfoot Glacier and Harrison Glacier flow?
_____
Blackfoot Glacier Harrison Glacier

(15) Are most of the features observed on this map depositional or erosional features? _____

C. Holy Cross, Colorado

(1) What was responsible for eroding the valley that extends to west of Turquoise Lake? _____

(2) Where did it stop? _____

(3) What is the name of the landform that contains the lake on its eastern side?
_____

(4) Why are there depressions on this feature? _____

(5) Is the landform referred to in Question 3 depositional or erosional? _____

D. Mt. Rainier

This area indicates what the Chief Mountain area must have looked like when the glaciers occupied the upper reaches of the valleys.

(1) The glaciers on Mt. Rainier have extended further down valley than they do today. What evidence can you give to account for their retreat?

_____

E. Yosemite Valley

(1) Determine the valley (Merced Gorge--Yosemite Valley) shape at the following locations: 37°42'30"N and 119°37'30"W.

_____ _____
37°42'30"N (diagram) 119°37'30"W (diagram)

(2) At what longitude does the valley shape change from that observed at 37°42'30"N? _____ longitude west?

(3) What was/is the sculpturing agent at 119°37'30"W - 37°42'30"N?

_____ _____
37°42'30"N 119°37'30"W

(4) Where did the ice stop flowing in Yosemite Valley? _____

(5) Why is the Merced River meandering east of El Capitan meadow? _____

_____

(6) Explain what you should call Bridalveil Falls (geologically) and how it formed?

_____

II. CONTINENTAL GLACIATION

A. Use your atlas or the map of the United States on the board and locate the area shown on the following maps: Whitewater, Wisconsin; Catskill, New York; Mt. Desert, Montana; and Kingston, Rhode Island. Are they located north or south of the Ohio and Missouri rivers? _____

(1) On the basis of your response to the above question, what type of glacial activity affected the areas shown on the maps? _____

(2) What is the significance of the two rivers mentioned in Statement A? _____

_____

(3) Is it possible that any glacial landforms will be found south of the rivers?

_____

B. Whitewater, Wisconsin

(1) In the northwestern corner of the map, there are numerous small hills called: _____

(2) Draw a cross section along the long axis of one of them and indicate the direction the ice moved with an arrow. Show north in the appropriate position.

Cross Section

(3) Examine the stream pattern and other water features. Do they appear typical of other landscapes developed by stream erosion? Explain. _____

_____

(4) What term applies to this drainage pattern? _____

(5) Describe the area of rough land extending from Whitewater Lake in the southwest to the eastern margin of the map. Suggest the process responsible for this kind of topography. _____

_____

(6) Locate the map in relation to the Ohio and Missouri rivers. Is the landform you referred to in Question 5 the most southerly feature of its type in the Untied States? _____ yes/no. Explain. _____

_____

(7) Why do lakes such as Peters Lake, Pleasant Lake, Blue Spring, and Spring Lake occur? _____

(8) Is the landscape shown on the map the result of deposition or erosion? _____

C. Mt. Desert, Catskill, and Kingston

(1) In what direction did the ice sheets of the Pleistocene advance through these areas? _____

(2) What evidence do you see to substantiate this? _____

(3) (Catskill, NY) What would you theorize to be the composition of Cross Hill versus Blue Hill?

_____ _____

Cross Hill Blue Hill

(4) (Kingston, RI) What would you theorize to be the composition of Green Hill versus Great Neck?

_____ _____

Green Hill Great Neck

(5) What are the proper geologic names for the above hills? _____

_____

(C) Coastal Processes

Version A

I. POINT REYES QUADRANGLE

(1) What kind of coastal feature is Chimney Rock (off the southeast edge of Point Reyes) an example of? _____
Locate on the map and give the name of another example of this type of landform. _____

(2) What depositional feature is found along the mouth of Drake's Estero?
_____

(3) Locate and name an example of a headland/pocket beach configuration. _____
_____

(4) Why is there an accumulation of sediment (mud) in Drake's Estero? _____
_____

(5) Give a possible reason why there is no beach accumulation along the inside of Point Reyes (from Drake's Beach to the end of the Point). _____
_____

(6) Locate and identify an eolian feature (landform shaped by wind). _____
_____

Version B

POINT REYES

Point Reyes National Seashore is an area of beautiful beaches and spectacular sea cliffs near San Francisco. Look at Point Reyes itself (SW part of the map). South of BM 552 is a headland projecting out into the water. What is the name for the features just offshore from the headland? _____ Are these erosional or depositional landforms? _____

Find Abbotts Lagoon in the west-central part of the map. What process has cut it off from the ocean? _____

Now look at Limantour Spit (about seven kilometers NE of the Point). What is the direction of the littoral drift along this part of the coast? (East to west, or west to east.) _____.

In places along Point Reyes Beach (western coast) the sand is over one kilometer from the ocean. How do you think it got there? _____

What is the prevailing wind direction here? (Hint: you may have to delve back into your pre-midterm knowledge for this one.) _____

There is a structural feature which formed Tomales Bay. What is it? (Hint: Point Reyes National Seashore is on the Pacific plate while the rest of the land area on the map is on the North American plate.) _____

At the southern end of Tomales Bay the streams have deposited much of their sediment. What kind of feature has this created? _____

Is Coast Creek (38°00'N, 122°48'W) an example of dendritic or annular drainage? _____

Look at Double Point (SE corner of map). What term describes the beach between the headlands? _____

Version C

This entire exercise refers to the Point Reyes Quadrangle.

1. Locate Point Reyes Beach. Based on the distribution of sand along this beach and inland from the beach, what is the prevailing wind direction (out of the NE, SE, NW, SW)? _____

2. Abbotts Lagoon has been sealed off from the ocean by a barrier beach. What coastal process has caused this? _____

3. Near the lighthouse on Point Reyes the contours are spaced very close together. What type of feature is this? _____ Is this an erosional feature or depositional feature? _____

4. What is the term used to describe the bending of waves around a headland such as Point Reyes? _____

5. Looking at Drake's Estero, is this a submergent or emergent coast? _____ Specifically, what is this type of coastline called? _____

6. Looking at Limantour Spit, what is it composed of? _____ Which direction is the littoral drift (east or west)? _____

7. Locate and name an example of a headland/pocket beach configuration. _____

8. Find Chimney Rock on the southeast coast of Point Reyes. What type of coastal landform is this? _____ Locate and give the name of another example of this type of landform. _____

9. Find Coast Creek in the southeast portion of the map. What type of drainage pattern is this? _____

10. Find Alamere Creek and Alamere Falls in the very southeast portion of the map. Considering the longitudinal profile of Alamere Creek, what type of feature does the waterfall represent? _____

11. Roughly sketch what the longitudinal profile of Alamere Creek looks like in the space below. Label a few elevations on the profile.

12. What type of depositional feature is located at the southeast end of Tomales Bay? _____

13. What type of drainage pattern is associated with this type of feature? _____

14. What major California fault is responsible for the linear shape of Tomales Bay? _____ (Also notice the sharp bend in the stream just east of Olema. This is also caused by the fault. If you follow Olema Creek southeast from Olema, you will notice small marsh areas. These are referred to as "sag ponds" and are typical of fault zones in many places.)

15. What type of marine mammal would you expect to find near SEA LION cove, located on the south edge of Point Reyes? _____

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